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A SKETCH
OF THE
GEOGRAPHY AND GEOLOGY
OF THE
HIMALAYA MOUNTAINS AND TIBET

BY
COLONEL S. G. BURRARD, R.E., F.R.S.,
SUPERINTENDENT, TRIGONOMETRICAL SURVEYS,

AND
H. H. HAYDEN, B.A., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA

PART IV
THE GEOLOGY OF THE HIMALAYA



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TIBET.

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S. G. BURRARD.

H. H. HAYDEN.

LIST OF CONTENTS.

1. The principal peaks and their altitudes (<i>S. G. Burrard</i>)	..	..	1
2. Notes on certain of the great peaks (<i>S. G. Burrard</i>)	..	..	7
3. On the names of certain peaks (<i>S. G. Burrard</i>)	..	..	15
4. On the errors of the adopted values of height (<i>S. G. Burrard</i>)	..	..	23
5. On the frequency with which peaks of certain heights tend to occur (<i>S. G. Burrard</i>)	..	..	31
6. On the geographical distribution of the great peaks (<i>S. G. Burrard</i>)	..	..	36
7. The geology of the great peaks (<i>H. H. Hayden</i>)	..	..	44
8. On the origin of mountain ranges (<i>H. H. Hayden</i>)	..	..	47
9. Observations of the plumb-line and pendulum	..	..	51
10. The Himalaya as represented upon maps	..	..	57
11. The Hodgsonian controversy	..	..	60
12. The high plateaux of Asia	..	..	64
13. The principal mountain ranges of Asia	..	..	71
14. The ranges of the Himalaya	..	..	75
15. The ranges of Southern Tibet	..	..	91
16. The Karakoram and the Hindu Kush	..	..	97
17. The ranges of Northern Tibet and Turkistan	..	..	103
18. The ranges of the interior of Tibet	..	..	109
19. The limit of perpetual snow	(<i>S. G. Burrard</i>)	..	116
20. The Drainage of the Plateaux	..	..	119
21. The Himalayan Rivers : introduction	..	..	131
22. The Rivers of the Kumaun Himalaya	..	..	135
23. The Rivers of the Nepal Himalaya	..	..	144
24. The Rivers of the Assam Himalaya	..	..	153
25. The Rivers of the Punjab Himalaya	..	..	161
26. The Indus	..	..	171
27. The Himalayan Rivers : summary	..	..	178
28. The River-gorges of the Himalaya	..	..	184
29. The Glaciers of High Asia (<i>S. G. Burrard and H. H. Hayden</i>)	..	..	192
30. The Lakes of Tibet and Turkistan (<i>S. G. Burrard and H. H. Hayden</i>)	..	..	198
31. On the origin of lakes	..	..	202
32. Geological subdivisions of the Himalaya	..	..	207
33. The Sub-Himalayan zone	(<i>H. H. Hayden</i>)	..	209
34. The Himalayan zone	..	..	218
35. The Tibetan zone	..	..	230

LIST OF CONTENTS.

36. Past history of the Himalaya	)	..	..	..	249
37. Age of the Himalaya	}	(<i>H. H. Hayden</i>)	..	..	258
38. Economic Geology of the Himalaya		..	..	..	265
APPENDIX		(<i>S. G. Burrard</i>)	..	..	268
GEOGRAPHICAL INDEX.					
INDEX OF SUBJECTS.					

LIST OF ILLUSTRATIONS.

Chart to illustrate the trends of the principal mountain ranges of the Himalayan and Trans-Himalayan system	..	..	<i>Frontispiece.</i>
Nojli Tower	..	..	<i>facing p. 30.</i>
Pictures by Colonel G. Strahan, R.E.	..	..	<i>facing p. 39.</i>
Chart	I.—Peaks of the first magnitude.		
„	II.—Peaks of the second and first magnitude.		
„	III.—Peaks of the third and higher magnitudes.		
„	IV.—Peaks of the fourth and higher magnitudes.		
„	V.—Peaks of the fifth and higher magnitudes.		
„	VI.—Panoramas of the Himalaya in Nepal and Sikkim.		
„	VII.—Panoramas of the Himalaya in Kumaun.		
„	VIII.—Panorama of the Himalaya between the Ganges and Sutlej.		
„	IX.—Parallelism between the borders of Peninsular India and the Himalaya.		
„	X.—The Kumaun Himalaya.		
„	XI.—Further representations of the Kumaun Himalaya.		
„	XII.—Brian Hodgson's theory.		
„	XIII.—Longitudinal section of the Great Himalaya.		
„	XIV.—Cross sections of the Himalaya.		
„	XV.—Cross sections of the Himalaya.		
„	XVI.—Bifurcations of the Great Himalaya range.		
„	XVII.—The terminations of the Great Himalaya range.		
„	XVIII.—Conjunction of ranges at the source of the Ravi.		
„	XIX.—Lessons from the Siwalik range.		
„	XX.—Longitudinal section of the Hindu Kush and Karakoram.		
„	XXI.—Conjunctions of ranges.		
„	XXII.—Routes of explorers in Tibet.		
„	XXIII.—Catchment areas of rivers and lakes.		
„	XXIV.—Himalayan areas drained by the Jumna and Ganges.		
„	XXV.—Himalayan areas drained by the Ramganga and Kali.		
„	XXVI.—Himalayan areas drained by the Karnali and Rapti.		
„	XXVII.—Himalayan areas drained by the Gandak and Baghmati.		
„	XXVIII.—Himalayan areas drained by the Kosi and Tista.		
„	XXIX.—Himalayan areas drained by the Raidak and Manas.		
„	XXX.—Himalayan area drained by the Brahmaputra.		
„	XXXI.—Himalayan area drained by the Sutlej.		

- Chart XXXII.—Himalayan areas drained by the Beas and Ravi.
 „ XXXIII.—Himalayan areas drained by the Chenab and Jhelum.
 „ XXXIV.—Himalayan area drained by the Indus.
 „ XXXV.—Water-partings are situated behind main ranges.
 „ XXXVI.—Gorges tend to recur on radial lines.
 „ XXXVII.—The varying gradients of rivers.
 „ XXXVIII.—Diagrammatic sections across the Himalaya.
 „ XXXIX.—Folding in the Sub-Himalayan zone.
 „ XL.—Geological map of Simla and Jutogh.
 „ XLI.—Geological map and sections of Naini Tal.
 „ XLII.—Tal series in Western Garhwal.
 „ XLIII.—Geological map of Spiti and Rupshu.
 „ XLIV.—Sections across the Tibetan zone in Spiti, Tibet and Kumaun.
 „ XLV.—Sections across the Tibetan zone in Spiti, Kumaun and Hazara.
 „ XLVI.—Geological map and sections of Malla Johar.
 „ XLVII.—Geological map of the Provinces of Tsang and U in Tibet.
 „ XLVIII.—Geological map of Kashmir.
 „ XLIX.—Geological map of Hazara.
 „ L.—Geological map of the Himalaya.

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PREFACE

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CONTENTS OF PART IV.

	PAGE
PREFACE	i
32. Geological subdivisions of the Himalaya }	207
33. The Sub-Himalayan zone	209
34. The Himalayan zone	218
35. The Tibetan zone	230
36. Past history of the Himalaya	249
37. Age of the Himalaya	258
38. Economic Geology of the Himalaya .. } (H. H. Hayden.)	265
APPENDIX (S. G. Burrard). ..	269

PLATES IN PART IV.

PLATE XXXVIII.—Diagrammatic sections across the Himalaya.
PLATE XXXIX.—Folding in the Sub-Himalayan zone.
PLATE XL.—Geological map of Simla and Jutogh.
PLATE XLI.—Geological map and sections of Naini Tal.
PLATE XLII.—Tal series in Western Garhwal.
PLATE XLIII.—Geological map of Spiti and Rupshu.
PLATE XLIV.—Sections across the Tibetan zone in Spiti, Tibet and Kumaun.
PLATE XLV.—Sections across the Tibetan zone in Spiti, Kumaun and Hazara.
PLATE XLVI.—Geological map and sections of Malla Johar.
PLATE XLVII.—Geological map of the Provinces of Tsang and U in Tibet.
PLATE XLVIII.—Geological map of Kashmir.
PLATE XLIX.—Geological map of Hazara.
PLATE L.—Geological map of the Himalaya.

THE GEOLOGY OF THE HIMALAYA.

32

GEOLOGICAL SUBDIVISIONS OF THE HIMALAYA.

THE rocks of the Himalaya fall into three broad stratigraphical zones (Plate xxxviii), namely—

- (1) an outer or SUB-HIMALAYAN ZONE composed of sediments for the most part of Tertiary age ;
- (2) a central or HIMALAYAN ZONE, comprising most of the ranges known as the Lesser Himalaya together with the line of high peaks. This is composed of granite and other crystalline rocks and a great group of unfossiliferous sediments of unknown age ; and
- (3) a northern or TIBETAN ZONE, lying for the most part behind the line of high peaks (the axis of the Great Himalayan range) and composed of a series of highly fossiliferous sediments ranging in age from the Cambrian to the Tertiary epochs.

The following table shows the classification and the more important subdivisions :—

33

THE SUB-HIMALAYAN ZONE.

Although it is customary in stratigraphical treatises to deal first with the oldest rock-groups, it will be more convenient in the present instance to take the three zones in their geographical sequence, describing them in the order in which they would be met with by the traveller passing from the plains of India to the highlands of Tibet. Whether his route lie through the tropical forests of the Darjeeling Terai, the sal-covered spurs above Kathgodam, the outer ridges and duns of the Siwalik range below Mussooree, or the sinuous tunnels of the Kalka-Simla Railway, he must always cross a band of conglomerates, sandstones and clays, which runs from end to end of the Himalaya along their outer margin, and is known to geologists as the Sub-Himalayan zone. Even should his destination be the valley of Kashmir, he must still cross the same zone in the Murree hills and through the deep and narrow gorges of the Jhelum.

The rocks of this zone fall into two well-marked subdivisions, known as the Sirmur and Siwalik series, respectively: these, again, are subdivided as follows:—

Subdivisions of the component beds. and Siwalik series, respectively : these, again, are divided as follows :—

Sub-Himalayan system	.	.	{	Siwalik series	.	Upper Siwalik stage.
						Middle " "
						Lower " (Nahan) "
				Sirmur series	.	Kasauli stage.
						Dagshai "
						Subathu "

SUB-HIMALAYAN SYSTEM.

Siwalik series.

The upper, or Siwalik, series is the first rock-group met with in passing from the plains into the Himalayan foot-hills, and takes its name from the Siwalik hills, which are composed of the various members of this series. The uppermost stage consists of an immense thickness—many thousands of feet—of loosely aggregated conglomerates and soft earthy beds immediately underlying, but, as a rule, sharply marked off from, the extensive recent deposits still in process of formation along the foot of the Himalaya. Here and there, however, where the Siwalik beds have been subjected to comparatively little disturbance, no distinct line of division between them and the overlying recent deposits can be found, and, owing to the mutual similarity of composition, we are led to conclude that the recent deposits are the direct successors of the Upper Siwalik beds. Both are of sub-aërial origin, and both are the direct products of those forces of which the concrete embodiments are rain and rivers, and which are to-day at work, removing material from the mountains to lay it down again on the plains at their foot. To this process

not only the recent deposits, but clearly also the Upper Siwaliks, owe their origin. It has further been found that, in the neighbourhood of the debouchures of the great rivers of the present day, the Siwalik deposits consist chiefly of coarse conglomerates, whereas, in the intervening areas soft earthy beds predominate.* It is clear, therefore, that, throughout the vast period of time necessary for the accumulation of these deposits, the distribution of the main drainage lines of the Himalaya was much as it is at the present day, and the more important Himalayan rivers are therefore of very great antiquity.

The Upper Siwalik conglomerates are underlain by a great thickness of a soft, Middle Siwalik and Nahan barely coherent, sand-rock,† lying upon a harder but otherwise very similar sandstone: these two subdivisions of the Siwalik series are known as the Middle and the Lower, respectively, the latter being also frequently known as the Nahan stage, from its being exposed and having been first studied at Nahan.‡ As already stated, the three stages forming the Siwalik series are all composed of sub-aërial deposits which bear internal evidence of a fluvial origin. As might, therefore, be expected, fossils are rare, but the two uppermost stages have yielded locally large numbers of remains of mammals closely allied to Siwalik Fossils. species existing in the Himalayan foot-hills at the present day.

These include bones and teeth of such animals as the elephant, rhinoceros, tiger, pig, ox and various species of deer.§ Such fossils are by no means of common occurrence, but the few localities which have hitherto been discovered have yielded them in some profusion. The same belt of Siwalik deposits is known to extend far to the west, through the Punjab into Sind, whilst similar beds, also highly fossiliferous, have been found in Burma. Although there is an extensive literature on the subject of the Siwalik fossils as a whole, little is known as to their exact vertical distribution or their respective horizons in the rocks in which they occur, and a wide field for detailed research still exists in this direction. On the whole, however, it is generally agreed that they are of the same age as the very similar fossils found in Europe and known to belong to the pliocene stage of the Tertiary system.

The beds below the Upper Siwalik conglomerates—the Middle Siwalik or sand-rock stage—are composed chiefly of soft sands of a “pepper and salt” colour; here and there they contain small masses of lignite, which have frequently led to expectations of coal; such expectations, however, have invariably proved fallacious, and in all cases the lignite deposits have been found to be merely isolated pockets of carbonised wood|| or, in a few instances, patches of drifted vegetable matter¶ far too small to be of any economic value.

* *Manual of the Geology of India*, 2nd ed., 358 (1893); H. B. Medlicott, *Records, Geological Survey of India*, Vol. IX, 57 (1876).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

‡ H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864).

§ Falconer and Cautley: *Fauna antiqua sivalensis*; also *Palæontologia Indica*, ser. X.

|| H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2, 14 (1864); C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 26 (1890); H. H. Hayden: *Records, Geological Survey of India*, Vol. XXX, 249 (1897).

¶ F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XI, 46 (1875).

The lowest, or Nahan, stage differs from the Middle Siwalik in its greater degree of induration and, at times also, in its colour, the prevailing tints being brownish and greenish-brown, although bluish-grey is not uncommon, especially on weathered surfaces; the safest criterion by which to distinguish the members of the two groups, one from the other, is the greater degree of hardness characteristic of the Nahan sandstone, which is capable of being dressed into blocks and used as a building material, whereas the sand-rock is much less coherent and crumbles away when struck with the hammer.

Nahan stage.

Although the three stages of the Siwalik series may be denoted broadly as the conglomerate, sand-rock and sandstone stages, respectively, yet it must not be supposed that each of these rocks constitutes the whole of the formation of which it is characteristic; these are merely predominant types, and conglomerate is found also in the sand-rock stage, especially towards its base, as well as in the Nahan stage, whilst clay and loam are found throughout the whole series, purple and red clays being especially characteristic of the Nahan stage.

Lithological characters of the three stages.

Between the Siwalik series and all older beds with which they are found in contact there occurs one of the most peculiar, as it is one of the most constant, features of Himalayan tectonic geology. This is known as the "main boundary fault," which, probably throughout the whole length of the Himalaya, from Assam to at least as far as the Beas, occurs at the inner edge, and so forms the northern boundary, of the Siwalik series. This fault has many peculiar and interesting features: in the first place, it is not a simple fault, but is of the type known as "reversed," along which, in the process of folding, the older rocks have been thrust up over the younger, whilst, at the same time, the apparent order of superposition of the beds on one or on both sides of the fault may be exactly the reverse of the order in which they were originally deposited. Whatever be the ultimate causes to which the folding of the crust of the earth is due, they resolve themselves finally into tangential thrusts acting in opposite directions; the effect of this is to throw the crust into folds, which, at first gentle, gradually become more and more compressed until the pressure exceeds the breaking strain of the component rocks and fracture (faulting) results. This is most readily exemplified by means of diagrams; on plate xxxix, figures 1 to 3 represent successive stages in the compression and folding of a series of stratified rocks, from their simple wave-like beginnings up to the reversed and broken flexure which is the key to almost all the complicated puzzles of Himalayan structure, not only in the geologically young Sub-Himalayan area but also throughout the whole of the mountain masses between India and Tibet, as well as in the ranges of Afghanistan.

Main boundary fault.

If, now, we turn to the actual conditions of the rocks of the Sub-Himalayan zone, we find this type of structure clearly shown in the beautiful sections traced by Mr. Middlemiss in the area between the debouchure of the Ganges and Nepal. Plate xxxix, figures 4 to 6, which are

Character of the faults.

reproductions of Mr. Middlemiss' sections,* show not only one of these reversed fault but a whole series of them (figure 6), each separating one rock formation from another and occurring not only among the members of the Siwalik series, but also through the older beds of the unfossiliferous and metamorphic zone of the Lesser Himalayan ranges. It will be noticed that each of these fractures has taken place along the middle limb of the fold, *i.e.*, along the part lying between an anticlinal crest and its complementary synclinal trough, and that on either side of the fault the normal order of superposition of the beds has, in many cases, been reversed, the younger now appearing to underlie and dip beneath the older; this is a characteristic and constant feature in the relation of the beds of the Siwalik series to all older beds and also, to a great extent, to one another.

A second point of importance in connection with the main boundary fault lies in the fact that the Siwalik deposits never overstep this boundary line and are never found among the higher hills beyond, but are restricted to the zone fringing the foot of the hills. The main boundary must, therefore, mark an original limit of deposition of the Siwalik series. Furthermore, Mr. Middlemiss has inferred that the reversed faults lying to the south of the main boundary are also to a certain extent original limits of deposition for the beds lying immediately to the south of each, and that they consequently mark the approximate position of the mountain-foot as it was at the time of their formation. They were thus "not contemporaneous, but successional," each having been produced or at least completed at the end of the period during which the beds immediately to the south of it were deposited.† The detailed reasoning and careful observation which have led to the above conclusions and which we owe, first, to the genius of the late Mr. H. B. Medlicott, and subsequently to the skill and industry of Mr. C. S. Middlemiss, are too extensive and of too technical a nature to be dealt with here, but those who wish to pursue the matter further are referred to the original papers.‡ An admirable summary, by Mr. R. D. Oldham, of the whole question will be found in the second edition of the "Manual of the Geology of India," pp. 467 to 471.

Turning now to the Siwalik series as a whole, we find it to consist of an enormous thickness—averaging over 16,000 feet—of deposits, which, in spite of local unconformities, are undoubtedly one great conformable and connected formation,§ which has been deposited sub-aërially by streams and rivers|| along the outer margin of the Himalaya. The deposition of such a great thickness of material must have occupied a vast period of time, during which the area over which they were being laid down was steadily sinking. The cause of this persistent movement of subsidence is still a matter of controversy, and no

* *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 118, 119 (1890).

‡ H. B. Medlicott: *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864); C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

§ C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2, 29 (1890).

|| *Manual of the Geology of India*, 2nd edition, 358 (1893).

theory has been generally accepted, although that put forward by the Rev. O. Fisher had until recently many supporters. This has already been ably dealt with by Mr.

Rev. O. Fisher's theory.

Oldham,* whose modification of the theory seemed to satisfy all the requirements of the case. The theory is based on the hypothesis that the crust of the earth is comparatively thin, and rests upon a zone of material which is either fluid or has the properties of a fluid. As this inner portion contracts owing to loss of heat, the crust is left unsupported and, not being strong enough to bear the strain due to its own weight, will "yield along lines of weakness" and be "thickened both upwards and downwards" from a zone at certain depths below the surface. Above this zone, which has been termed the "neutral zone," "the material will, on the whole, be forced upwards and below it downwards." Mr. Fisher has most ingeniously explained not only the rise of the Tibet plateau but also the overfolding of the outer border of the Himalaya and the subsidence of the submontane tracts, whilst Mr. Oldham's amplification of the argument affords a complete explanation of all the observed phenomena.†

Of late, however, physicists have begun to question the validity of Mr. Fisher's premises and Major Dutton's theory of isostasy (see above, page 48) is now more generally accepted. Major Dutton assumes that, owing to the removal, by rain and rivers, of material from the mountains and its deposition on the plains at their foot, isostatic equilibrium has been disturbed and can be restored only by the rise of the denuded area and the subsidence of that portion over which the material has been deposited; we thus have an explanation of the manner in which these vast sub-aërial deposits may have accumulated in areas which have for a long period of time been steadily subsiding.

Sirmur series.

The Sirmur series is, with one exception, not known to occur to the east of the Jumna, but is extensively developed in the outer portion of the Lesser Himalaya to the west of that river. It has been subdivided into the three stages already noted (*supra*, page 209). Of these, the uppermost, or Kasauli, stage consists chiefly of sandstone, with subordinate beds of clay: the sandstone is grey or greenish in colour, at times hard, but, as a rule, rather soft and coarse, the upper beds being not unlike the sandstones of the Nahan stage. The apparent absence of marine fossils, the presence of remains of land plants, and the general similarity of the beds of the Kasauli stage to those of the lower beds of the Siwalik series leave little room for doubt that the Kasauli sandstone is of fresh-water origin. The stage takes its name from the hill station of Kasauli, where it is well exposed.

Dagshai stage.

The underlying Dagshai stage consists chiefly of grey or purple sandstone with beds of bright red or purple homogeneous clay. Both at Dagshai and on the ridge to the north of that station the beds are

* *Manual of the Geology of India*, 2nd edition, 471—477 (1893).

† *Ibid*, 473.

well exposed and readily recognisable in the road and railway cuttings. The only fossils found are worm-tracks and obscure markings ascribed to fucoids. It appears probable that these beds were deposited in lagoons or salt-water lakes: they thus constitute an intermediate stage between the overlying Kasauli beds of fresh-water origin and the underlying Subathu stage, which is definitely marine.

The Subathu stage—so named from the hill station of Subathu—consists chiefly of
 Subathu stage. “greenish-grey and red gypseous shales, with some subor-
 “dinate lenticular bands of impure limestone and sandstone,
 “the latter principally found near the top” of the stage.* At the base there is a peculiar ferruginous bed which bears a strong resemblance to the laterite so well known in the Indian peninsula. Fossils are common throughout the rocks of this stage, especially in the neighbourhood of Subathu.† The only forms that need be mentioned here are *Nummulites*, the presence of which leads to the inference that the Subathu stage corresponds to the eocene of Europe.

Near the base of this stage at Subathu, there is a seam of coal, which, however, is too impure and too crushed to be of any economic value.‡

The Sirmur series was first critically examined and described by Mr. Medlicott
 Distribution of the Sirmur series: (*op. cit.*) in the Simla region; it was subsequently traced
 by him westwards into Jammu § and thence linked up with
 the similar rocks of Murree and the Jhelum valley.||

The Sirmur series of Jammu is similar to that of the Simla region, with the excep-
 in Jammu; tion that the coal seams of the Subathu stage are here more
 extensive, and are underlain by thick beds of ironstone.¶

In the Murree hills nummulitic limestone and shales represent the Subathu stage,
 in the Murree Hills. whilst the two upper stages (Dagshai and Kasauli) are re-
 presented by the formation known as the Murree beds, the
 identity of part of which with the Kasauli stage has been proved by the occurrence in
 the Murree hills of fossil plants similar to those found in the Kasauli stage in the Simla
 region.** Similar fossils have also been found in the valley of the Ravi,†† which thus
 serves as a connecting link between the Murree and Simla regions.

The whole of the Sirmur series is one perfectly continuous and conformable group
 Age of the series. of deposits, there being a gradual transition, first, from the
 Subathu stage up into the Dagshai stage and thence from
 that into the Kasauli stage. The evidence afforded by fossils enables us to correlate the

* *Manual of the Geology of India*, 2nd edition, 350 (1893).

† H. B. Medlicott, *Memoirs, Geological Survey of India*, Vol. III, pt. 2 (1864).

‡ *Manual of the Geology of India*, 2nd edition, 350 (1893).

§ *Records, Geological Survey of India*, Vol. IX, 53 (1876).

|| A. B. Wynne: *Records, Geological Survey of India*, Vol. VII, 64 (1874); O. Feistmantel: *Records, Geological Survey of India*, Vol. XV, 51 (1882).

¶ R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

** O. Feistmantel: *Records, Geological Survey of India*, Vol. XV, 51 (1882).

†† H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 52 (1876).

Subathu stage with the eocene stage of the Tertiary system of Europe * and the Kasauli stage with the lower miocene.

It has already been pointed out that, to the east of the Jumna, the Sirmur series is only known to occur in one area. To the east of the debouchure of the Ganges and along the inner boundary of the Siwalik series, there is found a most complicated group of beds, amongst which the typical beds of the Subathu stage have been recognised not only by their lithological characters but also by their fossils.†

Where the Sirmur series has been found in contact with older beds, the junction between the two has always been found to be either a faulted or an unconformable one. Nevertheless, from a tectonic point of view, this series is more nearly associated with the old, frequently metamorphosed, beds of the central zone of unfossiliferous sediments, amongst which its component members have been intimately infolded, than with the younger Siwalik series and it extends beyond the strictly Sub-Himalayan hills into the ranges of the Lesser Himalaya, whilst, except in the western parts of the Himalayan area, it is marked off from the Siwalik series by the sharp line of the "main boundary." In all except its purely structural relations, however, it differs widely in every respect from the old unfossiliferous rocks of the Himalayan zone.

TAL SERIES AND HIMALAYAN GONDWANAS.

Before passing on to deal with the component parts of this latter zone, we must refer briefly to certain pre-Sirmur beds which are, from a stratigraphical point of view, more nearly related to this younger series than to the members of the older Himalayan zone. These include a small patch of beds immediately underlying the Subathu stage in western Garhwal to the east of the Ganges, and certain coal-bearing beds found along the southern foot of the Himalaya to the east of the Nepal Terai. The first of these is known as the "Tal series," and the latter comprise a small fragment of the well-known Gondwana system of Peninsular India.

The Tal series was first noticed by Mr. H. B. Medlicott in the valleys of the Tal and Bidasni rivers, affluents of the Ganges in western Garhwal,‡ and was subsequently traced for some distance in an easterly direction by Mr. C. S. Middlemiss.§ It comprises two subdivisions: a lower composed of sandstone, some conglomerate and a black carbonaceous shale containing plant remains, and an upper, indigo-coloured, calcareous grit, at times becoming a sandy limestone, full of broken marine fossils. On normal sections, this series lies immediately below the nummulitic beds of the Subathu stage, and is therefore older,

* D'Archiac and Haime: *Groupe nummulitique de l'Inde*.

† C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XX, 33 (1887), *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

‡ *Memoirs, Geological Survey of India*, Vol. III, pt. 2, 69 (1864).

§ *Records, Geological Survey of India*, Vol. XX, 33 (1887).

whilst the fossils, which are unfortunately too badly preserved for complete determination, indicate that it may possibly be referable to some part of the Jurassic system or at least to some member of the Mesozoic group of Europe. It is to be hoped, however, that fossils in a better state of preservation may yet be found in this area, and thus enable us to ascertain the exact age of this series, which is unique in comprising the only fossiliferous marine beds of pre-Tertiary age known to occur in close association with the unfossiliferous series of the Himalayan zone.

Along the southern foot of the Eastern Himalaya, from the Balasan river, which debouches at a few miles to the east of the Nepal frontier up to the Dikrang river in the Daphla hills on the Assam border, a band of highly crushed coal-bearing rocks has been found, first by Lieutenant-Colonel Godwin-Austen* in the extreme east, and subsequently by Mr. F. R. Mallet† in the Darjeeling Terai and the Duars, by Mr. G. E. Pilgrim‡ in the foot-hills of Bhutan, and by Mr. T. D. LaTouche§ in the Aka hills. The rocks of this series consist of sandstone, shale and coal, which, owing to the intense crushing to which they have been subjected during the building up of the Himalaya, have been locally changed to quartzites, slates and carbonaceous schists. The coal beds, being the softest, have suffered most, and have been rendered so friable that they crumble into powder with the least handling; at the same time what were once probably continuous beds have been squeezed out into lenticular patches; these characteristics detract largely from the economic value of the coal-seams, and have rendered futile all attempts at mining enterprise. A number of fossils have been found in these rocks in the Darjeeling area and include such well-known genera as *Vertebraria* and *Glossopteris*,|| plants eminently characteristic of the coal-measures of Bengal. On the whole, the fossils, as well as the lithological characters of the rocks in which they occur, offer conclusive proof that these Himalayan beds represent the Damuda series of the Lower Gondwana system. The importance and interest of this group of beds are obvious, since they afford evidence of the northeasterly extension of the old Gondwana continent.

How far this belt of Damuda rocks is continuous along the foot of the Eastern Himalaya, it is at present impossible to say; but since it has been met with at most points at which the lower hills have been visited between the eastern frontier of Nepal and the Dikrang river, it is highly probable that its continuity is practically uninterrupted, whilst it may not improbably extend still further towards the east. The whole of the Eastern Himalaya, however, from the Sankos river to the gorge of the Brahmaputra is practically a *terra incognita*, in which much work of absorbing interest still remains for the geographer as well as for the geologist. Towards the west also these beds may possibly extend into Nepal, but of this there is no evidence. The only part of the country regarding which we have any

Gondwanas in the Eastern Himalaya.

Distribution of the Gondwanas.

* *Journ. As. Soc. Bengal*, Vol. XLIV, pt. 2, 35 (1875).

† *Memoirs, Geological Survey of India*, Vol. XI, 14 (1875).

‡ *Records, Geological Survey of India*, Vol. XXXIV, 24 (1900).

§ *Records, Geological Survey of India*, Vol. XVIII, 122 (1885).

|| F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XI, 30 (1875.).

information is the strip bordering the road to Katmandu, along which Mr. Medlicott found the Siwalik series well developed, but could not definitely identify any part of the section seen by him as being of Gondwana age.* No trace of the latter system has been found anywhere along the foot of the Himalaya to the west of Nepal, the only other extra-peninsular area in which plant-beds of Gondwana age have been identified being the valley of Kashmir (see below, p. 244).

* *Records, Geological Survey of India*, Vol. VIII, 93 (1875).

34

THE HIMALAYAN ZONE.

The next great group of rocks, which occupies what is known as the Himalayan zone, forms the bulk of the ranges constituting the Himalaya proper, and stretches from end to end of this mountain chain. To visitors to the hill stations it is the most familiar, yet at the same time the least understood, of all the Himalayan rock-groups and its classification still constitutes the greatest and most insoluble of all problems of Himalayan geology. It falls broadly into two subdivisions, (1) metamorphics, composed of granite, gneiss and crystalline schists and (2) a series of fragmental rocks of undoubtedly sedimentary origin, such as slates, quartzites, conglomerates and limestones, which, although frequently, to all appearance, eminently suited for the preservation of fossils, have not yet yielded to the most careful and repeated search a single trace of any undoubted organic remains.

The absence of fossils throughout the Himalayan zone renders it impossible to correlate, with any degree of certainty, the various rocks of one area with those of another since all attempts at such correlation can be based only on the individual peculiarities of the rocks themselves, that is to say, on their lithological characters, a method which, in the case of stratified rocks of undoubted sedimentary origin, is always more or less unreliable and not infrequently misleading, especially in areas in which disturbance and metamorphism are so pronounced as in the central zone of the Himalaya. The result of this is that, with rare exceptions, it has been impossible to recognise with certainty the petrographical elements of one area in those of another, and a large number of apparently independent rock-groups have consequently been established, each under a purely local name, thus giving rise to a confusing variety of subdivisions, no two of which can be definitely correlated the one with the other. Of these the best known are the "Simla slates" and "Carbonaceous system" in the Simla hills and Mussooree, the "Jaunsar system" in Jaunsar-Bawar, the "Purple slates," "Deoban limestone" and "Vaikrita system" of Garhwal and Kumaun, the "Baxa" and "Daling" series in the Darjeeling Himalaya and the slates and schists of the Miju ranges between North-Eastern Assam and Tibet.

GRANITE AND CRYSTALLINE SCHISTS.

In striking contrast with the amount of detailed attention that has been paid to the unfossiliferous sediments of the Himalayan zone, the metamorphosed schists and other crystalline rocks have, with one exception, been most strangely neglected. This has no doubt been largely due to the fact that the crystalline rocks, as a rule, lie in that "no man's land" between

Distribution and subdivision.

Crystalline belt.

the sedimentary Himalayan systems and the fossiliferous beds of the Tibetan zone, and have thus, owing to lack of time and opportunity, failed to receive attention at the hands of the respective investigators of these two belts of rocks. The one exception referred to is that of the gneissose granite of the Himalaya, which was most exhaustively studied by the late Lieutenant-General C. A. McMahon, whose work is a monument of patient

Gneissose granite.

investigation and a brilliant example of the great assistance that can be rendered by a non-professional worker in the field of Indian geological research. Of the many valuable results of General McMahon's work, the most important of all was the conclusive proof of the intrusive origin of the granite, which had hitherto been regarded as a metamorphic rock of probably sedimentary origin, and, under the name of the "central gneiss,"* had been described as the oldest of all Himalayan rocks, whereas he was able to show that it was in reality one of the youngest members of the Himalayan and Tibetan zones, into which it had been intruded, and with which it had been intimately infolded, whilst to it is due much of the metamorphism of the rocks amongst which it occurs. The period at which the intrusion of the Himalayan granite took place is not definitely known, but is usually

Age of the granite.

regarded as approximately coincident with the disturbances to which the origin of the Himalaya is ascribed and which occurred towards the end of the eocene division of the Tertiary period.

Fragments of granite have been found among the pebbles of the conglomerates in the old "Panjal" rocks of Kashmir (see below, p. 242) and in the "Kuling system" in Spiti (*infra*, p. 234); it is therefore evident that granite must have formed part of the land surface from which the materials that make up these beds were derived and must consequently have been older than Carboniferous, which is the latest date that can be attributed to the Panjals (*infra*, p. 245). It will be seen subsequently that at this period the Himalaya did not exist and this old granite must therefore be excluded from the term "Himalayan."

Three other granites are found in the Himalayan region. The best known of these is characterised by the presence of biotite (black mica) and the absence of the mineral hornblende. It forms almost all the high peaks of the great Himalayan range (*supra*, p. 44) and is the form commonly understood by the term "Himalayan granite." Associated with it is another granite characterised by the presence of black tourmaline (schörl), plagioclase feldspar and beryl; this rock occurs in the form of bands intruded into the biotite-granite and is therefore younger than the latter; the difference in age between the two, however, is probably not great, the tourmaline-granite being perhaps merely the residual portion of the magma which still remained molten after the separation of the biotite-granite, in which case they may be regarded as merely representing two stages of a single phase of intrusion.

Biotite-granite.

Schörl-granite.

* F. Stoliczka: *Memoirs, Geological Survey of India*, Vol. V (1866).

The remaining granite differs markedly in mineralogical characters from both of the foregoing and is especially characterised by the presence of hornblende and sphene. It was found to be common in the valleys of the Brahmaputra and Kyi Chu in the neighbourhood of Lhasa* and has also been noticed in the Upper Indus valley in Ladak, in Astor, in Gilgit† and again in the Hindu Kush in Afghanistan. In Tibet it was regarded as possibly a form of the common biotite-granite of the Himalaya modified by the absorption of lime from the rocks into which it had been intruded; but the type has now been found to persist over such a wide area that this explanation of its origin seems hardly satisfactory, and it should perhaps be regarded as a definite petrological type. The age of the hornblende-granite is not known with certainty; it has been shown by General McMahon to be older than the typical biotite-granite and was found in Tibet to be either later Cretaceous or post-Cretaceous. There is, therefore, no great difference in age between these granites and all three may possibly have been derived, by a process of differentiation, from the same magma, the hornblende-granite solidifying first, the biotite-granite next, and the tourmaline-granite last of all. The result of this is that each of the two older is penetrated by veins of the younger.

It has already been pointed out (*supra*, p. 44) that the axis of the great Himalayan range, the line of highest peaks, lies on a continuous zone of granite and associated crystalline rocks: this belt extends for some distance on either side of the axis and separates the old Himalayan sedimentary systems from the Tibetan zone to the north, at the same time sending out ramifications in all directions into both. Thus the granite extends down into Chamba on the west, to the Chur peak between Simla and Mussooree, far south into Nepal, Darjeeling and the Chumbi valley, and probably composes much of the mountains of Bhutan and the unknown regions further to the east.

The associated crystalline rocks can, to a certain extent, be proved to be merely the metamorphosed representatives of the adjacent sedimentary systems. This is especially the case in the western part of the Himalayan belt, as, for instance, in the valley of the Sutlej in Kanawar, where the kyanite-schists and garnetiferous mica-schists bordering on the fossiliferous system of the Tibetan zone are seen to pass horizontally into comparatively unaltered beds which belong structurally to the Haimanta system‡ (see below, p. 232).

Further to the east, in Kumaun and Garhwal, a schistose series has been described under the name of the Vaikrita system,§ part of which is probably of similar origin. Still further eastwards, in Northern Sikkim and the Assam Himalaya, this relationship between the granite and contiguous sedimentary beds is still traceable, but such metamorphism as can be ascribed with certainty to the granite extends to but

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† C. A. McMahon: *Quarterly Journal, Geological Society*, Vol. LVI, 340 (1900).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 9 (1904).

§ C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XXIII, 41, 159 (1891).

a short distance from the intrusive masses of this rock, and we are not justified in assuming that such rocks as compose the crystalline complex of the Upper Tista valley are the result of a single effort of contact-metamorphism. These include such types as pyroxene-granulite, graphitic biotite-gneiss and spinel-bearing crystalline limestone, all of which occur in the valley of the La-Chen river in Sikkim,* whilst pyroxene-gneisses have also been recently found by Mr. L. L. Fermor, of the Geological Survey, in the neighbourhood of the Pindari glacier in the Almora district of Kumaun† and presumably, therefore, amongst the rocks constituting the Vaikrita system.

Between these two areas, crystalline limestone and other metamorphic rocks are known to occur in the valley of Nepal,‡ and may possibly be the representatives of the rocks of the La-Chen valley in Sikkim. Crystalline limestones have also recently been brought by Mr. Claude White from Bhutan.

Thus we may regard the crystalline belt as composed of three elements, *viz.*, intrusive granite, metamorphic schists due probably to the action of the granite on the rocks into which it has been intruded and which it has partially absorbed, and, lastly, a series of old gneisses, schists, granulites and crystalline limestones, of which the advanced state of metamorphism cannot be attributed merely to the Himalayan granite. These latter rocks, in fact, bear a marked resemblance to certain Peninsular types which are found in Madras, Burma, Ceylon, the Central Provinces § and Rajputana, and which are referred to the Archæan, the oldest of all the Indian rock-groups. Far to the west, in North-Eastern Afghanistan, the Siah Koh and the mountain ranges to the south and west of Kabul are either completely formed of similar types or have a foundation of these old rocks upon which younger fossiliferous beds have been unconformably deposited. In the intermediate areas crystalline schists are found in Hazara,|| Gilgit and Kashmir,¶ and, though in part merely altered representatives of sedimentary beds, probably also include members of the Archæan group.

Thus it is difficult to escape from the conclusion that the axis of the Himalayan chain and of the associated ranges to the west is in part made up of true representatives of the oldest known group of rocks, and that these are merely the northerly extension of the similar rocks of the Indian Peninsula.

SEDIMENTARY SYSTEMS.

Throughout the whole of the Himalaya the crystalline axis is always separated by a belt of unfossiliferous sedimentary deposits from the band of Sub-Himalayan rocks which skirts the outer foot of the

* H. H. Hayden : *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† *Ibid.*

‡ H. B. Medlicott : *Records, Geological Survey of India*, Vol. VIII, 96 (1875).

§ The pyroxene gneiss found by Mr. Fermor near the Pindari glacier is said to be indistinguishable from similar rocks from the Central Provinces.

|| C. S. Middlemiss : *Memoirs, Geological Survey of India*, Vol. XXVI, 46 (1896).

¶ R. Lydekker : *Memoirs, Geological Survey of India*, Vol. XXII, 265 (1883).

mountains. On the west, in Kangra district, in the Simla hills, and thence as far as the Nepal frontier, this belt occupies the greater part of the Lesser Himalayan ranges; to the east of Nepal, however, the crystalline rocks approach nearer to the plains and the width of the sedimentary belt is reduced (Plate xxxviii). In the western areas it consists, as already pointed out, of a number of apparently unrelated groups denoted by local names, such as the "Jaunsar system," "Carbonaceous system," "Deoban limestone," "Purple slate and breccia series" and the "Massive limestone." In the east its component members are known as the "Daling" and the "Baxa" series, respectively.

Of the systems of the western area the Jaunsar is regarded as the oldest and is said to lie unconformably on the beds of the crystalline belt.*

Jaunsar system.

In eastern Sirmur the lowest member of the system is composed of slate and limestone, overlain by quartzite. Elsewhere the lower beds are not seen, and the quartzite lies directly on the crystalline rocks. Above the quartzites is a series of beds of trap, ashes and lava-flows, locally replaced partially by slate and limestone. In the Bangahal valley and again in northern Jaunsar a peculiar rock, composed of large boulders set in a fine-grained matrix, occurs in the lower beds of this system; it bears a curious resemblance to the so-called "boulder-slate" of the Blaini series (see below, p. 223) and, like it, has been attributed to the action of floating ice, large boulders having presumably been thus carried out to sea, or, at any rate, into tranquil water in which fine-grained deposits were at the same time being laid down. This system has not been definitely recognised out of Jaunsar and eastern Sirmur, but it may be represented by a series of purple slates and volcanic breccia found in western Garhwal to the east of the Ganges† and throughout the hills around Naini Tal.‡

The Jaunsar system in Jaunsar-Bawar is overlain unconformably by a massive grey limestone series, which has been named the Deoban

Deoban limestone.

limestone after the peak of that name north of Chakrata.

The same limestone overlies the purple slate series of western Garhwal and Naini Tal (Plate xli) and a somewhat similar rock has been observed to the south-west of the Chur peak between Mussooree and Simla, in the Shali peak to the north-east of Simla and again in Kulu.

The systems next to be described comprise the most widely distributed and most

Simla slates and Carbonaceous system.

readily recognised of all the subdivisions of the great complex of unfossiliferous sediments composing the Himalayan group.

They are known as the Simla slates and the Carbonaceous system, and have been studied in considerable detail first by Mr. H. B. Medlicott§ and subsequently by Lieutenant-General C. A. McMahon|| and Mr. R. D. Oldham.¶ The area in which they were first

* R. D. Oldham : *Records, Geological Survey of India*, Vol. XXI, 131 (1888).

† C. S. Middlemiss : *Records, Geological Survey of India*, Vol. XX, 26 (1887).

‡ C. S. Middlemiss : *Records, Geological Survey of India*, Vol. XXIII, 214 (1890).

§ *Memoirs, Geological Survey of India*, Vol. III (1885).

|| *Records, Geological Survey of India*, Vol. X, 204 (1877), XIV, 305 (1881) XV, 34 (1882), XVI, 35 (1883).

¶ *Records, Geological Survey of India*, Vol. XX, 143 (1887).

examined and on which their description was based is that lying between the inner edge of the Sirmur series, to the north of Dagshai, and Simla, but they are believed to extend thence both eastwards and westwards to beyond Mussooree on the one side and into the Chamba-Dalhousie region on the other.

The lowest member of the group consists of a series of slate and quartzite, well exposed throughout the ridges and valleys to the east of Simla, and seen all along the road from Sanjauli Bazar to Mashobra as well as on the outer slope of Elysium hill and the spurs below the Mall on the north-eastern side of Jako (Plate XL); to the visitor to Simla the slate is no doubt most familiar on the backs of coolies toiling up the steep "khud" sides and plodding laboriously along the Mall.

The next overlying subdivision is that known as the Blaini series, so called from the Blaini river below Solan, where it was first studied by Mr. Medlicott. This is the most characteristic and readily recognised member of the Carbonaceous system and has served as a means of correlating various exposures in widely separated areas throughout the Lesser Himalayan ranges. It consists essentially of a bed of slate—presumably originally deposited as a fine mud or silt—through which are scattered sometimes pebbles of white quartz, sometimes large boulders of quartzite and other rocks. The large size of these boulders and the extremely fine-grained nature of the matrix in which they lie has led to a comparison of the Blaini "boulder-slate" with the "till" or "boulder clay," a characteristic deposit among the pleistocene or glacial beds of Europe, and which was formed by the instrumentality of floating ice during the Great Ice Age. Were the till to undergo severe pressure, such as the beds of the Himalayan zone have time and again been subjected to, the result would undoubtedly be a rock very like the Blaini boulder-slate for which a glacial origin has consequently also been inferred.*

The upper part of the Blaini series consists of a thin band of limestone, sometimes blue but typically pink or buff in colour. Occasionally this bed is absent, but in the Simla area it is almost invariably to be found above the boulder-slate. A conspicuous outcrop of the limestone occurs at Simla in the steep bank above the Mall, just beyond the Lakkar Bazar, whilst the boulder-slate is particularly well exposed at the Sanjauli corner beyond the Mayo Institute (Plate XL).

Above the Blaini series is a bed of black carbonaceous shale, which, owing to its colour, has frequently been mistaken by the inexperienced for coal, and has led to many a vain expectation of the discovery of this mineral in Simla on the hill-side above the "Ladies' Mile."

This is overlain by a thick series of quartzite and schist, known as the Boileauganj series in the Simla area, where it forms the greater part of Jako above the Mall and underlies most of the town.† Its

* *Manual of the Geology of India*, 2nd edition, 133 (1893). The name "tillite" has recently been introduced for indurated boulder-clays of glacial origin and pre-pleistocene age.

† R. D. Oldham: *Records, Geological Survey of India*, Vol. XX, 143 (1887).

thickness is very variable, ranging from only about 20 feet on the Krol mountain near Solan to perhaps a thousand at Simla.

The carbonaceous shale and overlying quartzite and schist (Boileauganj series) were grouped together by Mr. Medlicott, who named them the "Infra-Krol" series, on account of the fact that at the Krol mountain they underlie a thick band of limestone which caps both the Krol and the Boj, and which he, therefore, named the

Krol series.

"Krol limestone." At Simla the Boileauganj series is overlain also by limestone, but with it are associated beds of carbonaceous shale and igneous rocks, including a garnetiferous hornblende-schist, which is found on the summit of Prospect hill; these igneous beds have been regarded as altered volcanic ashes, but their origin is very obscure. In other localities beds of basalt have been found interbedded with the upper members of the Carbonaceous system.

To the east, in Jaunsar, a thick series of quartzite, which has been named the "Bawar quartzite," has been observed in the Tons and Pabar valleys; it is overlain by volcanic beds, followed by carbonaceous slates and limestones, and has been taken to represent the Boileauganj quartzite and overlying beds of the Simla area.

Also, in Jaunsar, but not in direct contact with the above series, there is a thick group of quartzite, slate, limestone, conglomerate and boulder-beds, lying unconformably on the Deoban limestone. These are known as the Mandhali series, and have been correlated, owing to the presence of boulder-beds, with the Blaini series of Simla. A very similar series occurs on the eastern flanks of the Chur mountain, where it is overlain by carbonaceous slates and a thick formation of quartzite and schist exactly like the Boileauganj series; this has been regarded as fairly conclusive evidence in favour of correlating the Bawars and Mandhalis with the lithologically similar series of the Carbonaceous system.

Beyond the Simla area, towards the west, beds regarded as the representatives of the Blaini series have been found in Chamba; further to the west, in Kashmir, Mr. Lydekker has described a boulder-bed belonging to his Panjal system* as the exact counterpart of the Blaini rock, whilst certain conglomerates and limestones so far off even as Chitral have been referred to the same horizon.†

The rocks described as the Panjal system in Kashmir consist of a thick series of deposits composed of quartzite, slate and conglomerate (boulder-beds) below, capped by great masses of volcanic beds, frequently amygdaloidal, which represent old lava-flows. These are exposed on the Pir Panjal range, from which they take their name; a good section or part of them is seen along the cart-road, on the left bank of the Jhelum between Uri and Baramula; they also form the hills on which Gulmarg stands. The upper or volcanic part of the system composes most of the hills sur-

* *Memoirs, Geological Survey of India*, Vol. XXII (1883).

† C. A. McMahon: *Quarterly Journal, Geological Society*, Vol. LVI, 337 (1900), *Geological Magazine*, Dec. IV, Vol. IX, 7 (1902).

rounding the Kashmir valley on its northern and north-western sides from Baramula to Vihi, and is particularly well seen on the Gilgit road between Bandipur and Tragbal and in the immediate neighbourhood of Srinagar. In an easterly direction the Panjal beds are said to extend to Chamba,* where they include the beds supposed to represent the Blaini series of Simla.

Still further westwards, in Hazara, a series of conglomerate and sandstone has been described by Mr. Middlemiss under the name of "Infra-Trias," and has been correlated by him also with the Blaini series of the Lesser Himalaya† (Plate XLIX).

We thus see that the unfossiliferous sedimentary belt is composed of a patch-work of more or less isolated groups of beds, no two of which can, with absolute certainty, be identified one with the other. For the most part they consist of perfectly ordinary sediments such as have been formed at all times during the earth's history, at least since its surface was divisible into land and water, and are still forming round the coasts and in the seas of the present day. Consequently, so far as these deposits are concerned, correlation depends on the manner of association of the respective deposits; thus, quartzites overlain by carbonaceous shales and limestones in one area are correlated with a similar sequence in another. This method of correlation by lithological characters is unfortunately open to many objections and cannot be relied on except over very limited areas. Where, however, a peculiar and uncommon form of deposit occurs in two neighbouring areas, we are on safer ground in correlating the one with the other, and it is chiefly this method that has been employed throughout the Himalayan unfossiliferous belt. The Blaini boulder-slate is generally admitted to be of glacial origin,‡ and as boulder-beds of this character, now known as "tillites," are by no means of common occurrence, but have been formed under very special conditions, which are known to have recurred only at rare intervals in the history of the earth, the Blaini rock has been regarded as the key to the solution of the mutual relationships of the respective members of the sedimentary rocks of the Himalayan zone and, with the exception of the supposed boulder-slate of the Jaunsar system, all similar beds in this belt have been referred to the Blaini series. Nor has this procedure been restricted to the rocks of the Lesser Himalaya; it has been extended to certain supposed boulder-beds found in Spiti, in the Panjal system in Kashmir, in the Infra-Trias of Hazara and even so far afield as Chitral. All these have, by one observer or the other, been referred to the Blaini horizon, and this again has been correlated with the well-known Talchir boulder-bed, which is of undoubted glacial origin and which occurs below fossiliferous deposits of known age in the Salt Range and at the base of the Gondwana system of Peninsular India. The Blaini boulder-slate and its supposed representatives in other parts of the Himalaya have, therefore, all been referred to the Talchir horizon, that is to say, to about the Middle Carboniferous epoch of the European geological

* R. Lydekker : *Memoirs, Geological Survey of India*, Vol. XXII (1883).

† *Memoirs, Geological Survey of India*, Vol. XXVI, 22 (1896).

‡ T. H. Holland : *Records, Geological Survey of India*, Vol. XXXVII, 129 (1908).

time-scale. This method of endeavouring to fix the age of the Blaini boulder-slate and its supposed representatives is a perfectly legitimate one, and the conclusions arrived at have until quite recently been accepted as offering a not improbable solution; unfortunately, however, the beds in Spiti, which have been identified with the Blaini rock, have now been found to be perfectly ordinary conglomerates with only a superficial resemblance to tillite, whilst they have also been proved by means of fossils to belong to a horizon considerably younger than the Talchirs.* Again, the conglomerates of the Panjal system of Kashmir, as described by Mr. Lydekker,† occur at some considerable distance below the top of that system, and recent work near Srinagar has shown that the uppermost beds of the Panjal system, the traps, are probably older than the Talchir boulder-bed;‡ consequently the Panjal conglomerates must be older still.§ Since, therefore, the correlation of the Blaini boulder-slate with the conglomerates of Spiti and Kashmir, which are comparatively near the Simla area, have proved erroneous, we must regard with suspicion any attempt to refer to this horizon beds in areas so far off as Hazara and Chitral. It must be admitted, however, that the wide distribution of the Talchir tillite, which has been identified both in Australia and South Africa, would justify its extension to the Simla area, but it must be remembered that in all other areas it is found associated with fossiliferous rocks of known age, and it is therefore extremely difficult to account for the absence of fossils in the Blaini series; this might no doubt be attributed to the disturbance and crushing to which the Himalayan group as a whole has been subjected, were it not for the fact that beds no less crushed and altered have been found in other areas to retain their fossils in a recognisable state, whereas the rocks of the Himalayan zone, although often apparently eminently suited for the preservation of fossils, have not yielded so much as a trace of any structure that can be definitely pronounced to be of organic origin, much less any recognisable fossils. We are, therefore, compelled to conclude that these rocks are truly unfossiliferous and to give up further attempts to correlate them with the fossiliferous beds of known age constituting the Tibetan zone to the north. There has consequently of late been a general tendency to look elsewhere for the representatives of this great unfossiliferous group. Attention has been drawn to this point by the Director of the Geological Survey in a "General Report" on the work of his Department; Sir Thomas Holland|| writes —

The fossiliferous character of the strata lying on the northern (Tibetan) flanks of the crystalline axis stands in remarkable contrast to the unfossiliferous character of the beds which form the southern or Lower Himalayan zone. The persistence of the northern fossiliferous zone eastwards as

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, 51, 109 (1904).

† *Memoirs, Geological Survey of India* Vol. XXII, 216 (1883).

‡ H. H. Hayden: *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907).

§ It seems not improbable that the Panjal system may include more than one set of conglomerates, namely, one of upper Cambrian or lower Silurian (Muth) age (*infra* p. 233), and another which occurs at the base of the Permian; both of these are found in Spiti and have each been referred to the Blaini boulder-slate. If both of these occur in Kashmir, there are grounds for suspecting that they may have been regarded as one and the same. This, however, cannot be settled until Kashmir has been surveyed in detail.

|| *Records, Geological Survey of India*, XXXII, 156 (1905).

Far as Sikkim, now established, naturally accentuates this contrast, and increases the suspicion, which has recently been growing amongst the members of the Geological Survey, that the Lower Himalayan rocks, like those of Simla, Kumaun and Bhutan, are members of very ancient systems of sediments, all or in part pre-Cambrian, nothing other, in fact, than northerly extensions of the Vindhyan, Cuddapah and similar old systems of the Peninsula, which have been caught, like the much younger Gondwana beds of Darjeeling and Assam, in the great earth-folds that have produced the Himalayan range. That one, two or more stratigraphical stages on the south could be unfossiliferous whilst their equivalents on the north are fossiliferous might be possible; that such an accident could be carried through every geological epoch from Cambrian to Cretaceous is so highly unlikely, that we are driven to regard the ingenious and elaborate systems of lithological correspondences, which have been propounded to distribute the strata of the Lower Himalayan zone over the standard fossiliferous scale, as so much misdirected, though well intended, mental energy.

That this solution is a nearer approximation to the truth is becoming yearly more and more apparent. It has already been pointed out (*supra*, page 221) that rocks exactly resembling Archæan types of the Indian Peninsula and Burma have been found in Sikkim, Kumaun and Afghanistan, and it is not unreasonable to suppose that they will also be discovered in the intermediate areas; furthermore, the Daling series of Sikkim and the metamorphic and crystalline rocks of the Miju ranges at the extreme eastern end of the Himalaya have also been referred to well-known Peninsular types* and we are thus led to correlate the Himalayan group with the old unfossiliferous and metamorphic beds comprised in the Archæan and Purana groups† of the extra-Himalayan areas, which include such systems as the Vindhyan, Cuddapahs, Dharwar and that embracing the old gneissose rocks of Rajputana, the Central Provinces, Madras and Burma and so to regard this unfossiliferous belt as a northerly extension of what has been one of the most permanent, as it is one of the oldest, continental areas of the globe.

The presence, immediately to the north of this zone, of an extensive series of fossiliferous marine sediments, further points to the conclusion that here lay the southern shores of the Tethys, the sea which extended over most of Asia during Palæozoic and Mesozoic times. Its old littoral deposits can still be traced among the beds of the Tibetan zone and prove that much of the present Himalaya was a land surface even in early Cambrian times (see below, page 250); and the unconformities and overlaps found at various horizons in the Palæozoic systems are indications of the vicissitudes through which this part of the ancient continent has passed.

Exception may perhaps be taken to the correlation of the unfossiliferous Himalayan zone with the Archæan and Purana groups of Peninsular India on the ground of the absence from the latter area of any known glacial deposits of pre-Gondwana age resembling the Blaini boulder-slate. A somewhat similar rock, however, has been recorded as occurring among the Purana rocks of Rewa.‡ Certainly no great weight

* J. M. MacLaren: *Records, Geological Survey of India*, Vol. XXXI, 181 (1904).

† See table showing classification of Himalayan systems: *supra* p. 208.

‡ *Memoirs, Geological Survey of India*, Vol. XXXI, 132 (1901).

can be attached to this observation, since definite proofs of glacial origin, such as striation and facetting of the included pebbles, have not been obtained. It nevertheless indicates the possibility of a pre-Talchir glacial epoch on the Indian Peninsula. In this connection attention may be drawn to the extraordinary resemblance, amounting indeed almost to identity, of some of the old pre-Cambrian groups of rocks of India to those of South Africa: thus the Dharwar system is very similar to the Malmesbury series of Africa. In much later times the Gondwanas of India find their exact equivalents in the Karroo system of the Cape, whilst similar mutual resemblances can be traced between the Cretaceous deposits of the two areas. The intimate relationship of India to South Africa in later Palæozoic and Mesozoic times has long been known,* but it is only quite recently that the more extensive geological surveys of South Africa have revealed the close resemblance between the older rock-groups of the two areas and have shown that from earliest times until comparatively recently the geological histories of the two areas have been strikingly similar. Many points of resemblance also exist between the geology of Australia and that of the Indian Peninsula and the recent discovery of boulder-beds of undoubted glacial origin below the Cambrian rocks of South Africa,† China‡ and (?) Australia§ render it by no means improbable that glacial conditions existed also in India in pre-Cambrian times and left their record in the form of the Blaini boulder-slate.

In the eastern Himalaya, the unfossiliferous rocks are represented by the Daling and Baxa series. The former consists of green and grey silky slate, quartzite and, occasionally, beds of hornblende schist. These beds are much crushed and contorted, and frequently contain small deposits of copper-ore, which have long been mined in primitive fashion by the natives of the Darjeeling district. The series occupies the lower hills between the crystalline rocks of Darjeeling and the Damudas of the foot-hills (Plate xxxviii, fig. 3), and extends up along the Tista valley into Sikkim; thence it runs eastwards into Bhutan and probably continues through the unknown ranges on the north of Assam.||

In the foot-hills of Bhutan another set of rocks, composed chiefly of dolomitic limestone and quartzite and known as the Baxa series, from the hill-station of Baxa, is found between the Damudas and the Dalings. Neither of these series has yielded any fossils, nor have they any special lithological features in common with individual members of the subdivisions into which the unfossiliferous rocks of other parts of the Himalaya have been grouped. Like these latter, however, they are now referred to the pre-Cambrian systems of the

* *Manual of the Geology of India*, 1st edition, Vol. I (1879).

† A. W. Rogers in *10th Annual Report of the Geol. Commission of the Cape of Good Hope*, 162 (1905).

‡ Bailey Willis, Eliot Blackwelder and R. H. Sargent: *Research in China*, pt. 1, 267 (1907).

§ Rev. W. Howchin: *Quarterly Journal, Geological Society*, Vol. LXIV, 234 (1908). The age of the South Australian tillite here referred to is regarded by Dr. Howchin as Cambrian, but all Australian geologists are not agreed upon this point, some considering it to be part of the Permo-Carboniferous boulder-bed and so homotaxial with our Talchir tillite.

|| F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XI, 39 (1875); P. N. Bose: *Records, Geological Survey of India*, Vol. XXIV, 217 (1891).

Indian Peninsula, of which they probably constitute merely an outlying portion. The metalliferous Dalings in some respects resemble the Dharwars, whilst the rocks of the Baxa series may find their nearest relatives among the members of the Cuddapah system.

Both the Daling and the Baxa series always appear to overlie the crushed representatives of the Damuda series and also the beds of the Sub-Himalayan zone, which fringe the southern mountain-foot. For this reason they were formerly regarded as possibly younger than the Damudas, but we now know that one of the most persistent features of the tectonic geology of the Sub-Himalayan zone is the manner in which the younger formations appear to dip below and underlie the older beds in the higher hills, a feature which we have seen to be due to recumbent folds and reversed faults; and when we find that each higher member is more metamorphosed and more crushed than that below, we may safely assume that the apparent sequence is the reverse of the true one and that, as in the case of the Tal series and associated rocks in western Garhwal, the Daling is in reality older than the Baxa series and the latter older than the Damudas.

35

THE TIBETAN ZONE.

The most northerly of the three zones of the Himalaya embraces not only the northern part of this mountain range, but extends far into Tibet and comprises one of the most complete representations of the geological record to be found in the world, ranging, as it does, from almost the earliest period of which there have yet been obtained any unequivocal organic remains down to the Tertiary epoch. Between these extreme limits not a single period remains unrepresented, for, although there may be local gaps in one area, these are bridged over in another; and as a book may be restored in its entirety from a number of incomplete copies, so the geological record may, with the exception of a few pages at the beginning and a few at the end, be pieced together from the editions lying open in the mountains of Kumaun, Spiti and Kashmir.

Throughout the Himalaya, this northern, or Tibetan, zone is met with almost everywhere immediately behind the crystalline axis—the line of high peaks—of the great Himalayan range. It embraces the Ladak and Zangskar ranges with their intervening troughs, and extends far to the north, probably at least to the great lake basin of Tibet and possibly as far as the Kuen Lun range. It consists of a vast thickness—more than 20,000 feet—of sediments almost entirely of marine origin and represented by such rocks as slate, sandstone, conglomerate and limestone. Along its southern border it is in contact with the Himalayan granite, which throws out branches ramifying through and metamorphosing the component members of the sedimentary zone.

Fossils had long been known to occur to the north of the great Himalayan range, the sacred “saligram”* of the Hindus having been identified as an ammonite related to those found in the Jurassic beds of Europe, and as early as the year 1831, the presence of genera common in the European Palæozoic and Mesozoic systems had been recorded in the Himalaya.† No systematic work, however, was undertaken till some years later, when General Sir R. Strachey visited the Kumaun Himalaya and Ngari Khorsum‡ and laid the

* “Saligram” are ammonites brought into India chiefly from the Jurassic shales of Kumaun, Ngari Khorsum and the uplands of Tibet on the northern frontier of Nepal. They are to be found in Hindu temples in India, and are also worn as charms. Among the Buddhists of Tibet they are also regarded as having magical properties and are used in certain mystic rites. Serat Chandra Das also draws attention to the presence of fossils among the offerings to the gods in Densa-til monastery near Samye on the Brahmaputra [*Journey to Lhasa and Central Tibet*, edited by W. W. Rockhill, p. 299 (1904)].

† *Gleanings in Science*, Vol. III, 30 (1831).

‡ Spelt Nari Khorsam in previous parts, but the more correct form has now been substituted. We have experienced great difficulty in dealing with Tibetan names, since no phonetic system has yet been universally adopted. In the case of Indian names, we have decided, for the sake of consistency, to adopt the orthography of the Imperial Gazetteer, but, in dealing with names of Tibetan origin, we feel that this course would lead to needless perpetuation of error and have decided to employ the nearest possible approximation to the correct pronunciation. Thus, according to recognised standards of transliteration, the name Ngari Khorsum is written in Tibetan (m)Nga(h)-ri(s) (h)Khor-(g)sum; the letters in brackets, being silent letters, may be elided, thus leaving the name as pronounced—Nga-ri Khor-sum. In the case of Zangskar, we also follow the Tibetan spelling in preference to the form “Zaskar” employed in the Imperial Gazetteer; the Tibetan form is Zangs (d)kar, which, in Central Tibet, would be pronounced Zang-kar, but in Ladak Zangskar. This is very near the form Zanskar sanctioned by long usage, which, however, has latterly been discarded for Zaskar, presumably the nearest approximation to the Tibetan word that the Kashmiri is capable of. [H. H. H.]

foundations of Himalayan stratigraphical geology. He was followed by Dr. F. Stoliczka, whose description and subdivision of the fossiliferous rocks of Spiti*—a valley lying to the north of Kulu—long served as the basis for the classification of the sedimentary rocks of the Tibetan zone. Simultaneously the work of Lieutenant-Colonel Godwin-Austen† and of Verchère‡ proved the extension of this zone into Kashmir, and the subsequent surveys of Kumaun, Ngari Khorsum and Spiti by Mr. C. L. Griesbach§ and of Kashmir by Mr. R. Lydekker|| both confirmed and amplified the results of Stoliczka's earlier traverses, whilst the publications of the Geological Survey Department bear witness to the amount of attention that the Tibetan zone has received in recent years.¶ Although much still remains to be done, and we can hardly claim yet to have advanced beyond the threshold of Himalayan stratigraphical investigation, nevertheless we have obtained sufficient evidence to reveal the striking fact that, throughout almost the whole period covered by that branch of geology known as "Historical Geology"—that is to say, that portion of the geological time-scale determined by the remains of living organisms—what is now the northern slope of the great Himalayan range lay beneath the waters of a sea, which extended over Tibet and stretched at one time to China and at another to the Mediterranean. Throughout almost the whole of this period, the sea-floor continued steadily to subside and thus rendered possible the deposition on it of those thousands of feet of sediments which have now been raised once more into dry land and form part of the highest mountain range in the world. This great series of fossiliferous sediments falls into a number of natural subdivisions which are not capable of exact adjustment to those of the European scale. Thus the

Correlation of the systems of the Tibetan zone with those of Europe.

clear line of division which is found in Europe between the Palæozoic and Mesozoic groups does not exist in the Himalaya, where beds of Permian age pass upwards by perfect gradation into others with Lower Triassic fossils. There is no break in the continuity of the deposits, and it is consequently impossible to define exactly where Palæozoic ends and Mesozoic begins. Similarly, a well-marked break in the Indian deposits may be bridged over by a perfectly continuous sequence in the rocks of Europe, and it has now been found impracticable to apply to the one region the nomenclature of the other. Hence the natural groups of the Himalayan sequence must for the most part be recognised as individual units, characterised by names of their own and referable only approximately to European equivalents.

The most marked break in the Indian stratigraphical sequence occurs at the base of the Talchir boulder-bed, and this has been adopted by Sir Thomas Holland as a datum line for the classification of all the post-Purana rocks, the beds found below this break being included in his

Classification of the deposits of the Tibetan zone.

* *Memoirs, Geological Survey of India*, Vol. V (1865).

† *Quarterly Journal, Geological Society*, Vol. XX (1864), XXI (1865), XXII (1866).

‡ *Journal, Asiatic Society of Bengal*, Vol. XXXV (1866), XXXVI (1867).

§ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

|| *Memoirs, Geological Survey of India*, Vol. XXII (1883).

¶ *Pal. Indica*, Series XV, Vols. I to V.

“Dravidian group” and those above it in the “Aryan group.”* These two divisions are clearly marked off from one another in the Salt Range and also in Kashmir, but there is some difficulty in demarcating them exactly in other parts of the Himalaya; and in the present state of our knowledge of Himalayan stratigraphy the dividing line between the two cannot be rigidly laid down.

The following table shows the subdivisions recognised in the rocks of the Tibetan zone :—

TABLE XLI.†

	System or subdivision.		Approximate European equivalent.
ARYAN GROUP.	KAREWAS of Kashmir ; OSSIFEROUS BEDS of Ngari Khorsum <i>Stratigraphical break.</i>		Pleistocene.
	NUMMULITIC LIMESTONE of Ngari Khorsum ; INDUS VALLEY TERTIARIES.		Tertiary.
	KAMPA SYSTEM		
	FLYSCH of Ngari Khorsum ; CHIKKIM SERIES ; GIUMAL SERIES.		Cretaceous.
	SPITI SHALES ; JURASSIC of Southern Tibet. KIOTO LIMESTONE.		Jurassic.
	LILANG SYSTEM.		Trias.
	KULING SYSTEM.		Permian.
DRAVIDIAN GROUP.	(in Kashmir)	(in Spiti) <i>Stratigraphical break.</i>	Carboniferous.
	ZEWAN STAGE.	PO SERIES	
	GANGAMOPTERIS BEDS. <i>Stratigraphical break.</i>	KANAWAR SYSTEM.	
	PANJAL VOLCANICS.		LIPAK SERIES
	MUTH SYSTEM.		Devonian.
<i>Stratigraphical break.</i>		Silurian.	
HAIMANTA SYSTEM.		Cambrian and possibly in part Pre-Cambrian.	

TIBETAN ZONE IN SPITI AND KUMAUN (PLATES XLIII, XLIV, XLV).

Haimanta system.

The Haimanta system was the name given by Mr. C. L. Griesbach‡ to a series of conglomerates, quartzites and slates found in the Kumaun and Garhwal Himalaya and immediately overlying the crystalline schists of the Vaikrita system. The passage from the one system into the other is often quite gradual and no hard and fast line can be drawn between the two. This is no doubt due to the fact that the Vaikrita system consists partly of sedimentary beds which have been metamorphosed by the Himalayan

* T. H. Holland : *Trans. Min. and Geol. Inst. of India*, Vol. I, 48 (1906).

† See page 272.

‡ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

granite and which are in all probability merely the altered representatives of the lowest members of the Haimanta system (see above, page 220). The greatest development of this system is found in the Kumaun and Garhwal Himalaya, but it is also seen in the mountains to the north of Kulu, in Spiti and in Lahaul. In Spiti, the uppermost beds have yielded trilobites similar to those found in the rocks of the Cambrian system in other parts of the world.*

Muth system.

The beds of the Haimanta system are overlain by a group of beds named by Stoliczka the "Muth series." In Kumaun and Garhwal the lowest member is a dark coral limestone with imperfect fossils, said to be of Ordovician age; this subdivision is not found in Spiti, the slates with Cambrian trilobites being overlain unconformably by a conglomerate composed of pebbles of the underlying rocks. The next bed, both in the eastern and western sections, is a red quartzite, the colour of which is very persistent and serves as an unfailing guide to the recognition of this subdivision; it contains no determinable fossils, but is overlain by limestone with corals—including the very characteristic species *Halysites catenularia*—trilobites and brachiopods, such as occur in the Silurian rocks of Europe. Above this is a remarkable band of white quartzite, which is a constant feature in Himalayan sections of this part of the fossiliferous series. It is known as the Muth quartzite, from the village of Muth in Spiti. At its base are some thin bands of darker quartzite containing a brachiopod [*Pentamerus* (?) *oblongus*] probably identical with a species common in the upper part of the Gothlandian of Europe. No fossils have been found in the main mass of the quartzite, which may be of either Gothlandian or Devonian age and probably represents a part of each system.

Kanawar system.

In parts of Spiti, but not in the more easterly sections of Kumaun and Garhwal, the Muth quartzite passes up into a thick series of limestone and shale containing at the base fossils which are possibly of Devonian age, but in its upper beds a rich fauna characteristic of the lower Carboniferous (Mountain Limestone) of Europe. This is overlain by about 2,000 feet of shale and quartzite containing two important fossiliferous horizons, the lower of which has yielded plant remains and the upper is characterised by great numbers of *Bryozoa*, amongst which the genus *Fenestella* is particularly common: this bed has consequently been named the "Fenestella shales."† It corresponds in age with the Upper Carboniferous of Europe. These two groups of beds, the limestone series and the shale and quartzite, have only been found

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

† *Ibid.*

completely developed in Spiti and Kanawar, being absent from Garhwal and Kumaun. The lower series is very well exposed in the valley of the Lipak river near Lio, a village on the right bank of the Spiti river just above its confluence with the Sutlej; it has consequently been named the Lipak series, whilst the upper beds, the shales and quartzites, are known as the "Po series," after the village of Po in lower Spiti. For convenience of reference the two may be grouped together under the name "Kanawar system."

The top of the Po series, which corresponds approximately with the end of the Carboniferous period in Europe, marks an important epoch in the stratigraphical history of the Spiti and Kumaun Himalaya. The shales and quartzites pass upwards into conglomerates composed of rolled boulders of limestone, slate, quartzite and

Break in continuity of deposits above the Kanawar system. granite derived from the erosion of the various older rocks, such as the Po quartzites, Lipak limestones and mem-

bers of the Haimanta system. It is thus clear that before the deposition of this conglomerate parts of the sea-floor, on which the older systems had been laid down, were raised up to form dry land, which then underwent erosion. Similar conditions prevailed throughout Garhwal and Kumaun and may have extended even further east, but the whole of the Nepal, Bhutan and Assam Himalaya is still unsurveyed and we know practically nothing of the geological conditions to the east of Kumaun. A group of beds, which has been described as the Dothak series,* at the lower end

Dothak series in Tibet.

of the Phari plain, may possibly cover a part of this period, whilst fossils of approximately the same age as those of the Fenestella shales have been found in rolled boulders in the gorge of the Subansiri in Assam† and thus afford evidence of the presence of fossiliferous beds somewhere in the catchment area of that river, but their relations to such older and younger beds as may be present are completely unknown.

In the Kumaun and Garhwal Himalaya the whole of the Po series, as well as the Lipak series, is wanting, and the overlying beds rest usually on an eroded surface of the Muth quartzite or, more rarely, on the underlying limestone. In Spiti and Kanawar extensive erosion took place throughout the greater part of the area before the deposition of the conglomerate which occurs above the Po series, but at both the upper and lower ends of the Spiti valley, the Lipak series and the Po series have been preserved.

Absence of Kanawar system from Kumaun.

Kuling system.

The next overlying series was first observed in Spiti by Stoliczka, who named it the Kuling series.‡ It consists of conglomerate at the base overlain by calcareous

* H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, part 2 (1907).

† J. M. MacLaren: *Records, Geological Survey of India*, Vol. XXXI, 186 (1904); C. Diener: *ibid*, Vol. XXXII, 189 (1905).

‡ *Memoirs, Geological Survey of India*, Vol. V, pt. 1 (1865).

sandstone which is covered in turn by a bed of black shale—about 150 feet thick—known as the “Productus shales”* on account of the predominance in it of brachiopods, which were originally referred to that genus. In Kumaun and Garhwal the presence

Productus shales.

of the conglomerate and overlying calcareous sandstone has not been recorded, but the Productus shales appear to lie directly on one or other horizon of the older systems. The fossils of the Productus shales are numerous and well preserved, and this horizon, together with the underlying sandstone and conglomerate, is regarded as approximately equivalent to the Permian system of Europe.

Lilang system.

The next overlying beds show a distinct change both in the character of the component rocks as well as in the fauna that they contain; for whereas the predominant elements of the Kuling system are shallow-water coastal deposits, such as conglomerate, sandstone and shale, containing the remains of brachiopods, the next group of beds consists chiefly of limestone, deposited for the most part in deeper water beyond the reach of the sand and mud derived from the neighbouring land. The fauna, too, comprises chiefly ammonites, with only a comparatively small percentage of brachiopods. The change, though rapid, is by no means abrupt; marine conditions still prevailed, but the sea-bottom slowly subsided and what was formerly a comparatively shallow-water area now became deeper and further removed from the shore. There was no interruption of continuity of deposition on the sea-floor nor any *sudden* change in the character of the deposits. It is consequently impossible in the Himalaya to draw any hard line between the top of the Palæozoic group and the base of the Mesozoic, the passage from one to the other being perfectly gradual. The Productus shales pass up into an alternating series of thin bands of shale interbedded with equally thin bands of impure limestone; as the series is followed upwards, the calcareous element increases and the shale disappears and thence there extends to a vertical thickness of over 6,000 feet a perfectly uninterrupted group of deposits of which the predominant rock is limestone, with subordinate bands of shale and sandstone. This vast series of marine sediments comprises representatives of all the members of the Mesozoic group of Europe, which can be readily identified by means of the numerous fossils that they contain. The most important subdivision, both in point of thickness as well as of fossil contents, is the Lilang system, which is over 3,000 feet thick in Spiti and rather less in the Kumaun and Garhwal Himalaya. The base of this system is regarded as lying immediately above the Productus shales and beneath a thin band of limestone known as the Otoceras zone, so called from the prevailing genus of ammonite found in it. The lower beds of the Lilang system correspond to the Lower Trias of Europe and possibly in part to the uppermost subdivision of the Permian system. They consist of thin bands of limestone and shale, passing upwards into a thick bed of nodular limestone. Part of this latter bed, together with a series of bands

* *Memoirs, Geological Survey of India*, Vol. XXIII, 66 (1891); XXXVI, pt. 1 (1904).

of limestone separated by thin partings of shale, represents the Muschelkalk of Europe, whilst the remainder of the Middle Trias, the Ladinic stage of Europe, is represented by shale and limestone containing the characteristic European fossil *Daonella lommeli*. Above this, again, are representatives of the Carnic and Juvavic stages of the Upper Trias (for correlation see below, p. 239).

Kioto Limestone.

From Spiti eastwards as far as the western frontier of Nepal, the Zangskar range is usually capped by a great mass of limestone, over 2,000 feet in thickness, which is for the most part unfossiliferous, but the uppermost beds contain a rich Jurassic fauna, whilst those at the base contain bivalves (*Megalodon* and *Dicerocardium*) characteristic of the Upper Trias. The upper part was named by Stoliczka the "Tagling limestone" and the lower the "Para limestone," of which the Tagling was intended to represent the Jurassic, and the Para the Triassic, part. Like most of the other Himalayan formations, however, this limestone mass cannot be subdivided according to the European scale; it is a well-characterised stratigraphical unit in which it is impossible to say where the Triassic part ends and the Jurassic begins. It is therefore necessary to have a single name for it, and in recent publications of the Geological Survey it has been referred to as the "Grey Limestone,"* in which term was included the whole limestone mass between the top of the Quartzite series of the Lilang system and the base of the Spiti shales. Unfortunately the term "Grey limestone" had already been applied to a subdivision of the Nummulitic series in Hazara† and to employ it also for the limestone of Spiti and Kumaun would lead to confusion. The latter might appropriately be called the "Kioto limestone," as it is well seen in the cliffs behind Kioto in upper Spiti. Of its two subdivisions the name Para stage is restricted to the beds containing *Megalodon* and latterly known as the "Megalodon limestone,"‡ whilst the Tagling stage includes all the rest.

All the subordinate stages of the European Trias have been recognised by their fossils, but the perfect continuity from base to summit of the stratigraphical sequence of the Mesozoic group in the Himalaya, where a single mountain-side not infrequently affords a complete section from the Productus shales to the top of the Spiti shales, renders it impossible to define the exact limits corresponding to those of the stages of the European Trias. The classification of the Himalayan sequence is, therefore, based on the natural subdivisions of its component beds which, according to their fossil contents, can be approximately referred to their European equivalents. Such correlation is facilitated by the large number of characteristic European species, particularly of ammonites, found also in the Himalayan Trias. The general resemblance of the fauna of the Trias of the Himalaya to that of the Alps is indeed so great as to lead to the

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902); C. Diener: *Pal. Indica*, ser. XV, Vol. V, No. 3 (1908).

† C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904); C. Diener: *op. cit.*

conclusion that during the Triassic epoch, the sea, known as the Tethys, which extended over much of Asia, was continuous with that in which the Trias of the Alps was being laid down, and that thus intercommunication took place between these two areas.

Spiti shales.

In Spiti, as well as in the Garhwal and Kumaun Himalaya, the steep limestone cliffs (Kioto Limestone) of the Zangskar range are usually capped by undulating downs covered with black friable shales. These are known as the Spiti shales and have yielded large numbers of ammonites and belemnites of Upper Jurassic type.*

Giumal and Chikkim series.

Here and there, resting on the Spiti shales, lie beds of sandstone, occasionally capped by limestone and shale; these are known as the Giumal sandstone, Chikkim limestone, and Chikkim shales, respectively, and have been so named after the villages of Giumal and Chikkim in Spiti; they have yielded few fossils, but such as have been found are of Cretaceous age.†

CLASSIFICATION OF THE ARYAN AND DRAVIDIAN SYSTEMS OF THE TIBETAN ZONE IN SPITI AND KUMAUN.

The above short description of the Palæozoic and Mesozoic rocks of the Tibetan zone is based on their development in Spiti and in the mountains of Kumaun and Garhwal, in which areas they have been studied in greater detail than elsewhere, whilst the sequence from the base of the Haimantas to the Chikkim shale is the most complete and continuous yet observed in any part of the Himalayan region. Even in these areas, however, much still remains to be done, especially in the direction of a detailed study and subdivision of the Kioto Limestone which embraces the uppermost Trias and the greater part of the Jurassic system.

The change from limestone to Spiti shales and Giumal sandstone marks the beginning of a new phase in the geological history of the Himalaya and Tibet. The Tethys gradually began to recede, its southern shores crept slowly northwards and areas, which, throughout almost the whole of the Triassic and lower Jurassic periods, had lain beneath a clear and tranquil sea, were now brought within reach first of mud and silt and then of sand and grit carried down by rivers from the south. Gradually the sea retreated until the northern ranges of the Himalaya and the whole of Tibet became a continental area. During the progress of this change, however,

End of marine and beginning
of continental phase in the
Himalayan area.

* F. Stoliczka : *Memoirs, Geological Survey of India*, Vol. V. (1865); V. Uhlig : *Pal. Indica*, ser. XV, Vol. IV (1903).

† F. Stoliczka : *op. cit.*

deposition continued for some time in Ladak, Ngari Khorsum and Central Tibet; the deposits thus formed are of lower Tertiary age and are partially marine and partially of fresh-water or estuarine origin. The former are found in Tibet and in Zangskar and the latter in the Indus valley in Kashmir. In Zangskar these Tertiary beds are represented by a mass of nummulitic limestone found at an elevation of 18,500 feet on the peaks above the Singhgi La,* whilst, further east, nummulitic limestone is said by Mr. Griesbach to overlie the Cretaceous beds in Ngari Khorsum, to the north-east of the Niti Pass.† The Tertiary rocks of the Upper Indus valley and of the more easterly portions of Tibet will be referred to subsequently (*infra*, p. 245).

None of these beds are younger than eocene, the oldest subdivision of the Tertiary system, and they thus furnish us with an approximate date for the close of the marine, and the opening of the continental, phase in the history of the Indo-Tibetan area; this date may be placed in the latter part of the eocene period of the Tertiary epoch. The crustal disturbances which then took place, resulting in the rise of the land and retreat and disappearance of the sea, were accompanied by great volcanic activity, evidences of which are now to be seen in the lava-flows associated with the Tertiary deposits and in the dykes of intrusive rock found cutting through all the older sedimentary deposits.

The annexed table shows the detailed classification of the Aryan and Dravidian rocks of Spiti and Kumaun.‡

THE "EXOTIC BLOCKS" OF MALLA JOHAR (PLATE XLVI).

Before passing on to discuss the development and distribution of the Palæozoic and Mesozoic beds in other parts of the Himalaya, it is necessary to refer to a very peculiar group of detached blocks of limestone and other rocks found in the extreme north of Kumaun on the Indo-Tibetan frontier and beyond in Ngari Khorsum (Hundes). The culminating ridge of the Zangskar range in Malla Johar and the northern slopes of the same range at Chitichun in Ngari Khorsum are composed chiefly of Spiti shales overlain by a sandstone formation (the equivalent of the Giupal sandstone of Spiti) which passes upwards into a series of sandstone and shale (probably of Cretaceous age) exactly resembling the European "Flysch." Overlying these and resting sometimes on the Spiti shales and sometimes on the flysch, and inextricably mixed with, and embedded in, masses of andesite and other basic volcanic rocks, are innumerable blocks of sedimentary rock, varying in size from mere pebbles to masses of many thousand cubic yards in volume. Blocks of limestone, sandstone, Spiti shale and flysch lie scattered through the volcanics

* T. D. LaTouche: *Records, Geological Survey of India*, Vol. XXI, 160 (1888).

† *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

‡ A. von Krafft: *General Report, Geological Survey of India*, 1899-1900 (1901);

H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904);

C. Diener: *Pal. Indica*, ser. XV, Vol. V, No. 3 (1903).

TABLE XLII.

SEDIMENTARY ROCKS OF THE TIBETAN ZONE IN SPITI AND KUMAUN.			Approximate European Equivalents.	
ARYAN GROUP.		Nummulitic limestone and Volcanics of Kumaun and Ngari Khorsum. "Flysch" of Kumaun and Ngari Khorsum. "Chikkim shales." "Chikkim limestone." "Giimal sandstone." "Spiti shales."	Eocene.	
			CRETACEOUS.	
			JURASSIC.	
	KIOTO LIME-STONE.	"Tagling stage." "Para stage."	Rhaetic and Dachsteinkalk	
	LILANG SYSTEM.	"Quartzite series" with <i>Spirigera maniensis</i> (Krafft). "Monotis shales" with <i>Monotis salinaria</i> (Schlotheim). "Coral limestone" with many corals and <i>Spiriferina griesbachi</i> (Bittner). "Juvavites beds" with <i>Juvavites angulatus</i> (Diener). "Tropites beds" with <i>Tropites cf. subbullatus</i> (Mojsisovics). "Grey shales" with <i>Joannites cymbiformis</i> (Wulfen). "Halobia beds" with <i>Halobia cf. comata</i> (Bittner). "Daonella limestone" with <i>Daonella indica</i> (Bittner). "Daonella shales" with <i>Daonella lommeli</i> (Wissman). "Muschelkalk;" limestone with <i>Ptychites rugifer</i> (Oppel). "Nodular limestone." "Hedenstræmia beds" with <i>Hedenstræmia mojsisovicsi</i> (Diener). "Meekoceras zone" with <i>Meekoceras varaha</i> (Diener). "Ophiceras zone" with <i>Ophiceras sakuntala</i> (Diener). "Otoceras zone" with <i>Otoceras woodwardi</i> (Griesbach).	Juvavic.	TRIAS.
			Carnic.	
			Ladinic.	
			Muschelkalk.	
			Lower Trias.	
			? ?	
KULING SYSTEM.	"Productus shales" with <i>Xenaspis</i> and <i>Cyclolobus</i> above and <i>Marginifera himalayensis</i> (Diener) below. "Calcareous sandstone" with <i>Spirifer fasciger</i> (Keyserling) and <i>Spirifer marcoui</i> (Waagen). Conglomerate, grit and sandstone.	PERMIAN.		
KANA-WAR SYSTEM.	"Po series" including "Fenestella shales" with <i>Protoretepora ampla</i> (Lonsdale). "Lipak series;" chiefly limestone with <i>Syringothyris cuspidata</i> (Martin) above and <i>Atrypa aspera</i> (Schlotheim) below.	CARBONIFEROUS.		
DRAVIDIAN GROUP.	MUTH SYSTEM.	"Muth quartzite" with <i>Pentamerus cf. oblongus</i> (Sowerby) at base. Limestones with Trilobites, Brachiopods and Corals (including <i>Halysites catenularia</i> Lamarck). "Red quartzite." Conglomerate in Spiti and coral limestone in Kumaun.	DEVONIAN.	
			SILURIAN.	
	HAI-MANTA SYSTEM.	Slate, quartzite and limestone with trilobites. Blue and black slate (weathering bright red), with carbonaceous shales. Slate and quartzite. Conglomerate in Kumaun,—absent from Spiti.	CAMBRIAN and (?) PRE-CAMBRIAN.	

with no trace of regularity or arrangement, whilst the jumble becomes the more confused when the fossiliferous character of certain of the blocks reveals the striking fact that almost every stratigraphical horizon from Permian to uppermost Cretaceous finds its representative in one or other individual block. Unfossiliferous blocks prevail, but those which contain fossils have yielded specimens both sufficiently numerous and sufficiently well preserved to leave no room for doubt as to the particular horizon to which each belongs. When, however, we compare them with the corresponding horizons of the typical Palæozoic and Mesozoic sequence of Spiti and Kumaun, they are found to show a very marked difference both in their physical character and in the fauna that they contain. Thus the curious fact is revealed that in one and the same area, and almost in contact with one another, there are two distinct facies of Permian, Triassic and Jurassic rocks, the one being the typical Spiti-Kumaun facies and the other that of the exotic blocks. The latter, therefore, cannot be merely fragments of the underlying beds which have been brought into their present anomalous position on the top of beds younger than themselves by a simple process of faulting to which the origin of certain of the European "Klippenzüge" or "blocs exotiques" has been ascribed; but they must have been transported from some other area, where the upper Palæozoic and Mesozoic facies is different to that of the typical Tibetan zone. Such an area may possibly be found to lie to the north, in Ngari Khorsum, which is still a *terra incognita*, but perhaps contains the solution of one of the most interesting problems of Indian stratigraphical geology.

The invariable association of these exotic blocks with great masses of lava and other volcanic rocks of sub-aërial origin affords a clue to the manner in which they have been transported to their present position. During the great outburst of volcanic activity which took place throughout the northern parts of the Himalaya and in western Tibet in early Tertiary times, these blocks were torn by the disruptive forces from their parent mass and carried on the lava-flows far to the south of their original home.*

THE TIBETAN ZONE IN THE EASTERN HIMALAYA (PLATE XLVII).

We shall now try to follow the Tibetan zone from the typical areas of Spiti and Kumaun into other parts of the Himalaya. We have already seen that in these two districts the only points of difference in the oldest (Dravidian) group of the fossiliferous rocks is the absence from Spiti of the Lower Haimanta conglomerate and of the coral limestone which occurs at the base of the Muth system in Kumaun† and the presence in lower Spiti of an extensive series of beds, the Kanawar system,‡ which has not been found in any part of Kumaun.

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902). For other literature on the subject of the Exotic blocks see *Records, Geological Survey of India*, Vol. XXVI, 19 (1893), *Denkschr. d. k. Akad. Wien.*, LXII, 533 (1895); *Memoirs, Geological Survey of India*, Vol. XXVIII, 1 (1895); *Pal Indica*, ser. XV, Vol. I, pt. 3 (1897); Vol. II, pt. 3.

† *Memoirs, Geological Survey of India*, Vol. XXIII (1891); XXXVI, pt. 1 (1904).

‡ *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

The development of the Aryan group is almost identical in the two areas, but in Kumaun the Lilang system is not quite so thick as in Spiti. As the Tibetan zone is followed south-eastwards towards Nepal, this thinning out of the Lilang system (Trias) is very marked, the total thickness in Byans being only 2,000 feet as compared with over 3,000 feet in Spiti. East of Kumaun practically nothing is known of the Tibetan zone until we reach the northern frontier of Sikkim, where there is a very extensive development of Jurassic beds, which appear to cover almost the whole of this part of Tibet from Sikkim and Bhutan on the south to beyond Lhasa. The limestones of the Lhonak range, north of Kinchinjunga, and a small group of limestones at the south-eastern edge of the Phari plain, probably represent parts of the Trias and the Lias of Europe, and the hills which run from Kam-pa Dzong to Tuna contain an interesting group of limestone and shales (Kam-pa system) of Cretaceous and Lower Tertiary age.* The fossiliferous boulders of Permo-Carboniferous age, found near the mouth of the Subansiri river in Assam, have already been referred to (*supra*, p. 234).

Thus we see that little is known of the Tibetan zone to the east of Kumaun, but it is highly probable that Mesozoic rocks (chiefly Spiti shales and other Jurassic beds) run continuously eastwards along the northern frontiers of Nepal and Bhutan, possibly even as far as the gorge of the Brahmaputra.

KASHMIR AND THE WESTERN HIMALAYA (PLATE XLVIII).

Returning once more to our central area and proceeding north-westward and westward from Spiti, we find an extensive development of the Tibetan zone in Kashmir. In the year 1883 Lydekker published an account of the geology of Kashmir and adjoining territories,† based on his own surveys and upon the work of previous observers, amongst whom the names of Drew,‡ Godwin-Austen,§ Verchère|| and Stoliczka¶ are conspicuous. This work was completed before detailed surveys of Spiti and Kumaun had been carried out and his classification of the rock-groups of Kashmir is on broader lines than that since adopted for the latter areas. He recognised four main systems in the rocks of Kashmir, viz. (1) "Tertiary," (2) "Zanskar," (3) "Panjal," and (4) "Crystalline and Metamorphic."

The crystalline and metamorphic rocks, which consist of granite, gneiss and schist, cover the greater part of Northern Kashmir, including Baltistan, and run west-wards through Chilas and Gilgit into the mountains of Afghanistan. Towards the east they run through northern Ladak and probably continue thence through Western Tibet (Rudok) and Chumurti into the mountainous regions north of lake Manasarowar and the head-waters of the

* *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

† *Memoirs, Geological Survey of India*, Vol. XXII (1883).

‡ *The Jummoo and Kashmir territories* (1875).

§ *Quarterly Journal, Geological Society*, Vol. XV, 221 (1859), XX, 383 (1864), XXI, 492 (1865), XXII, 29 (1866), *Journal, Royal Geographical Society*, XXXI, 30 (1859).

|| *Journal, Asiatic Society of Bengal*, Vol. XXXV, pt. 2 (1866), XXXVI, pt. 2 (1867).

¶ *Memoirs, Geological Survey of India*, Vol. V, pt. 1 (1865), pt. 3 (1866).

Brahmaputra. In Eastern Kashmir they constitute much of the district of Zangskar, sending out a narrow arm south-eastwards through Lahaul to join the similar rocks of the great Himalayan range between Kulu and Spiti, and thus merging into the crystalline axis of the Himalaya.

In south-west Kashmir a narrow strip of crystalline rocks runs along the Pir Panjal range, forming a narrow tongue protruding from the wider crystalline area of Chamba and the Dhauladhar range, which, again, is an offshoot from the crystalline axis of the Himalaya.

The prevailing type amongst the rocks of this series both in Zangskar and in the Pir Panjal is the characteristic Himalayan biotite-granite, and these two crystalline areas are the result of the bifurcation of the hitherto unbroken central zone of the Himalaya. The crystalline zone, which crosses the Sutlej, as a single broad band, from east to west, splits up in Kangra district into two branches, one of which, following the range between Kulu and Spiti, runs through Lahaul into Zangskar, where it ends in the Nun Kun peaks. The other branch, still maintaining their distribution. much the same trend, passes through the Dhauladhar range into the Pir Panjal, where it thins out to a narrow strip, separated only by a band, of insignificant width, of pre-Tertiary rocks from the Sub-Himalayan zone of Jammu and the Murree hills.

Between these two branches of the crystalline zone lies a broad area of sedimentary rocks belonging to Lydekker's "Panjal" and "Zanskar" systems, which correspond approximately with the Dravidian and Aryan groups, whilst along the north-east of the Zangskar branch runs the direct continuation of the Tibetan zone of Spiti. Throughout Kashmir the sedimentary beds continue north-westwards until they meet the great crystalline complex of Baltistan, Gilgit and Chilas.

The outermost strip of sedimentary beds, which lies between the Sub-Himalayan zone of Jammu and Murree and the crystalline axis of the Pir Panjal range, has been included by Mr. Lydekker partly in his "Zanskar" system and partly in the "Panjal" system, which latter takes its name from the Pir Panjal range.

The "Panjal" system includes a great variety of rocks, all apparently devoid of fossils and consisting of slates, conglomerates and great masses of trap, representing old lava-flows; the slates and conglomerates prevail in the lower part of the system and the traps in the upper. The system completely surrounds the Srinagar valley and extends thence southwards along the edge of the crystalline zone of Zangskar. On the opposite side of the latter it runs north-west and south-west and is directly continuous with the Tibetan zone of Spiti. Small patches of the same system also occur at the lakes of Pangong and at Changchenmo near the frontier of Tibet.

The "Panjal" rocks of the western or Srinagar area differ from those of the eastern part of Kashmir; the upper division of the former is composed of great beds of trap, whereas this volcanic element is wanting in the latter area. No detailed subdivision of

the system was attempted by Mr. Lydekker, who correlated the whole of the Panjals with the Dravidian rocks of the Tibetan zone, that is to say, with the whole rock series extending from the base of the Haimantas to the base of the Kuling system. Such correlation may be correct for Eastern Kashmir, where the sedimentary rocks on the north-east of the Zangskar crystallines are the direct continuation of the Tibetan zone of Spiti.

In the western area, however, it is highly probable that the "Panjal" system, as found in Chamba and the Pir Panjal range, includes also members of the Himalayan zone of the Simla region, the beds of the latter area being probably continuous through Kangra and Chamba to the Pir Panjal, and also being represented in Jammu by the limestone formation known as the "Great Limestone," on which the Tertiary beds of the Sub-Himalayan zone rest unconformably.* Hence, in Western Kashmir, the "Panjal" system probably embraces representatives not only of the Dravidian members of the Tibetan zone, but also of the pre-Cambrian rocks of the Himalayan zone. Mr. Lydekker made no attempt to discriminate between these two, since he believed them to be one and the same, and a detailed survey must be made of Western Kashmir before the representatives of the two zones can be separated and compared.

The only fossils hitherto found in the Panjal rocks of Western Kashmir occur in a band of limestone, which is interstratified with beds of volcanic ash in the upper or trappean division of the "Panjal" system in the hills around Imsalwara (Ambersilwara) about 20 miles to the north of Baramula. The fossils are mostly encrinites and brachiopods, but only very badly preserved specimens have been found. This fossiliferous bed, the age of which may be Devonian or Lower Carboniferous, is at present unique in the "Panjal" system and is well worth the attention of travellers in Kashmir.

Above the "Panjal" system is a thick series of beds of which the prevailing rock is limestone, with some quartzites and shales near the base. This is Lydekker's "Zanskar" system, which he subdivided into three series, known as the Kuling, supra-Kuling and Chikkim series respectively. The Kuling series he regarded as the equivalent of the Productus shales (originally named by Stoliczka the "Kuling shales") of Spiti: the supra-Kuling series, which is composed chiefly of limestone, is the equivalent of the beds between the Otoceras zone (base of the Lilang system) and the base of the Chikkim limestone of Spiti, whilst the name, Chikkim series, was applied to the representatives in Kashmir of the Chikkim limestone and Chikkim shales.

The sedimentary rocks of Kashmir, although highly fossiliferous in certain localities, are, as a rule, much poorer in fossils than those of Spiti and Kumaun; this, combined with the fact that time did not permit him to carry out his work on the detailed

* H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 49 (1876); R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

scale that has since been possible in Spiti and Kumaun, led Lydekker to work on broad lines and to rely largely on the physical characters of the rocks as a guide to their correlation with one another and with those of adjacent areas. Consequently all the slates, conglomerates and traps were referred to one system, the "Panjal," and all important groups of limestone to the overlying system, the "Zanskar."

In order to correlate the "Panjal" and "Zanskar" systems with the fossiliferous groups of the Tibetan zone, we must turn first to that part of Kashmir which adjoins Spiti. Here we find that the sedimentary beds of the Tibetan zone run continuously from the one area to the other; although interrupted for a time by the crystalline area of Zangskar, the same zone can be followed north-westwards to Vihi, Dras, Tilail and Gurais, where, however, owing partly to lack of fossils but even more to the fact that no detailed survey of these areas has yet been made, only a few of the subdivisions of the typical Spiti sequence have been recognised. The most interesting, and now the best known, of the above areas is Vihi. Here the massive hills of trap, which extend along the northern edge of the Srinagar plain and constitute the uppermost member of the "Panjal" system, are overlain by shales and limestones. Immediately behind the village of Zewan, and again near the foot of the hills to the north-west of Khunmu, are the two most famous localities for fossils in all Kashmir. Immediately overlying the trap are bands of chert and shale, in the latter of which have been found remains of fishes and plants; these are of the greatest interest and importance, for the plants belong to the genus *Gangamopteris*, a form specially characteristic of the lower Gondwana beds of the Indian Peninsula; above the shale are the famous Zewan beds, which contain fossils identical with those of the *Fenestella* shales of Spiti. Overlying these, both at Khunmu and at the opposite side of the Vihi plain, are the *Productus* shales with their typical fossils, and above these, again, are limestones with Lower Triassic fossils similar to those of Spiti and Kumaun.* Thus, here, we have a link not only between the "Zanskar" system of Kashmir and the typical Tibetan zone, but also between both of these and the Gondwana system of the Peninsula.

We have seen that, in Spiti and Kumaun, there is an unconformable break between the beds below the *Productus* shales and all older deposits, thus indicating a period of disturbance which set in after the deposition of the *Fenestella* shales, when much of the old sea-floor was raised up to form dry land and was worn away by atmospheric agencies before it again sank beneath the waves. In Vihi there is no trace of this unconformity or break in the sequence between the Zewan beds—the equivalent of the *Fenestella* shales—and the *Productus* shales; marine conditions here continued uninterrupted; and whilst the more easterly areas were being raised up and denuded, this part of Kashmir remained continuously beneath the sea. On the other hand, the presence of terrestrial plants in the deposits below the Zewan beds and overlying the Panjal traps proves that the area in which

Upper Palaeozoic unconformity.

* H. H. Hayden: *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907); A. C. Seward: *Pal. Indica*, New Series, Vol. II, No. 2 (1905), *Records, Geological Survey of India*, Vol. XXXVI, 57 (1907).

these deposits now occur was either the estuary of a river, or, if covered by the sea, was at least very near the coast, whilst the Panjal traps may represent lava-flows over the surface of the neighbouring land. Fossils similar to those of the Zewan beds have also been found at Barus on the right bank of the Jhelum, Pahlgam in the Lidar valley and at several points in the hills at the south-eastern end of the Kashmir valley. Recently, too, similar fossils have been found on the Golabgarh Pass in the Pir Panjal range.

The lower part of the "Zanskar" system thus corresponds to the Lower Trias (Lower Lilang system) Productus shales and Fenestella shales of the Tibetan zone, and at the same time includes at its base beds which are correlated with the lower Gondwanas of the Indian Peninsula. The age of the Fenestella shales, and consequently of the Zewan beds, being upper Carboniferous, the underlying plant beds belong either to the middle or upper division of the same system and the

Panjal volcanic period.

Panjal traps, being older still, may be of either lower or middle Carboniferous age. Hence we see that, during the earlier part of the Carboniferous epoch, when the Lipak series of Spiti was being laid down under the sea, Eastern Kashmir was at least partly a land surface, studded with volcanoes from which were poured out the lavas which are now represented by the Panjal traps.* From the sea, which lay to the north-east, an arm ran out to Imsalwara, where fossiliferous limestones were laid down among beds of trap and ash. The shore probably lay along the northern side of the Kashmir valley either as a continuous land surface or a chain of volcanic islands and was connected through Chamba with the old continental area of the Himalayan zone. Towards the end of the Carboniferous epoch subsidence set in and the land gradually became submerged and was covered, first by estuarine muds in which remains of the land flora became imbedded, and, subsequently, by the Zewan beds with their marine fossils. Thenceforward marine conditions appear to have prevailed throughout the whole of the Triassic and Jurassic epochs, when Kashmir was part of the floor of the Eurasian sea, the Tethys.

Although the subdivision of the Himalaya into three zones, the Sub-Himalayan, Himalayan and Tibetan, which is so well marked eastwards of the Beas, is not so clearly defined in Kashmir where the crystalline rocks invade both the Tibetan and Himalayan zones and where the respective members of the two latter have not been satisfactorily distinguished one from the other, yet the outer, or Sub-Himalayan, zone is clearly

Indus valley Tertiaries.

marked off and can be traced through Jammu into the Murree hills and the gorges of the Jhelum. This zone of Tertiary rocks has already been described above (p. 214), but there remains a group of beds also of Tertiary age, to which reference has been made in connection with the Tibetan zone. These are the Indus valley Tertiaries, which extend as a long narrow strip in the valley of that river from eastern Ladak to Kargil. They are apparently quite unconnected with the Tertiaries of the Sub-Himalayan zone, and consist of conglomerates, sandstones and shales of fresh-water origin overlain by limestone with nummulites, which latter, it has already been seen, extends as far south as the Singhi

* See Appendix, p. 272, *infra*.

La in Zangskar (*supra*, page 238). With these Tertiary beds are associated great masses of volcanic rock, chiefly ashes and lava-flows.

The deposition of the nummulitic limestone seems to have been the final chapter in the marine history of the Himalaya and Tibet. With the outburst of volcanic activity the present or continental phase became established, and what had, for a lapse of time which must be counted in millions of years, been more or less continuously the floor of a great sea was now gradually raised up to form the highest mountain range on the face of the globe.

HAZARA (PLATE XLIX).

With the exception of Hazara, very little is known of the geology of the great belt of mountains which extends westwards and north-westwards from Kashmir. We have already seen that in Kashmir the regularity of arrangement of the rocks, which to the east of the Beas fall readily into three zones, an outer or Sub-Himalayan, a central or Himalayan and an inner or Tibetan, has disappeared and although the outer zone of Tertiary rocks still persists through Jammu into the Murree hills, the Himalayan and Tibetan zones cannot at present be completely separated from one another. In Hazara the fusion of the three zones becomes even more complete; the Sub-Himalayan is no longer separated from the Tibetan by the Himalayan and crystalline rocks, but the two are in direct contact and the lowest member of the Tertiary system is intimately infolded with the Tibetan facies of the Triassic, Jurassic and Cretaceous systems, whilst the latter are also found in association with a great series of unfossiliferous slates, which is regarded as the equivalent of the Himalayan zone as developed east of the Beas.

Concurrently with this change in the order of distribution of the three zones, the strike or trend of the rocks, which from Nepal to the Jhelum is on the whole S. E.-N. W., changes in Kashmir and bends round through E.-W. to N. E.-S. W. Consequent on this the mountain ranges also undergo a similar change of trend, and in Hazara run approximately from north-east to south-west. Nor is this bending of the ranges confined to the Himalayan chains, but is also reflected in the distant Salt Range of the Punjab.

The rocks of Hazara have been subdivided into seven series,* known as the Crystalline, the Slate series, the Infra-Trias, the Triassic, the Jurassic, the Cretaceous and the Tertiary. These form more or less parallel bands, with the youngest in the outer hills to the extreme south-east. The upper part of the Tertiary system of Hazara is merely the south-westerly continuation of the Murree beds; the lower portion or nummulitic series, consists of limestone, shale and sandstone with a band of coal. This series covers the greater part of S. E. Hazara, but where it has been removed by denudation the underlying beds of the Mesozoic group have been exposed. These represent the Upper Triassic, Jurassic and Cretaceous systems and include formations such as the Spiti shales and Giimal sandstone, typical of the Tibetan zone.

* C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

Beneath the Triassic beds is a series of rocks composed of limestone underlain by sandstone and shales which have a thick bed of conglomerate at their base. This is known as the Infra-Trias. It lies unconformably on a great group of unfossiliferous slates, the Slate series, which runs from north-east to south-west through the centre of Hazara. These slates, also known as the Attock slates, are probably the equivalent of the Simla slates of the Himalayan zone. The Infra-Trias series was regarded by Mr. Middlemiss as the equivalent of the Blaini series of Simla, and it is therefore probable that the Slate series and the Infra-Trias represent the old sedimentary beds of the Himalayan zone. Behind this, and forming most of north-western and northern Hazara, is a broad zone of granitic and crystalline rocks, the south-eastern portion of which consists of schists and gneisses, which may be partly Archæan but are to a great extent metamorphosed representatives of the Slate series and the Infra-Trias, which have been altered by contact with granite. The granite of this zone is the exact counterpart of the biotite-granite of the Himalaya, and we thus see in the crystalline zone the representatives of the Vaikrita system and the gneissose granite of the Himalayan zone. The great mountainous area lying between Northern Hazara and Northern Kashmir (Baltistan) on the one side and the Hindu Kush in longitude 70° on the other is still almost completely unsurveyed and deductions as to the geological conditions prevailing in that area can only be drawn from the few scattered observations which have been made in Gilgit and Chitral. The prevailing rocks appear to be granite and crystalline schists, but slates, quartzites and limestones, possibly representing the Dravidian members of the Tibetan zone,* occur in Hunza and Nagar, whilst beds of Devonian age have been found in the valley of the Kunar river in Chitral† and also on the Baroghil Pass‡ between Chitral and Wakhan. These rocks appear to strike towards the north-east and may possibly be connected with the fossiliferous series of Palæozoic age found by Stoliczka in the Little Pamir and Yarkand, and thus serve as a link between the Tibetan zone of the Himalaya and the sedimentary rocks of the Tian Shan.

AFGHANISTAN.

Between Chitral and the Kabul province of Afghanistan there is a broad tract of country, the western continuation of the Hindu Kush, of which nothing is known in detail but which appears to be composed chiefly of crystalline and metamorphic rocks such as occur along the lower reaches of the Kabul river below Laghman. So far as the rest of Afghanistan is concerned, there appear to be two broad stratigraphical facies separated the one from the other by the Koh-i-Baba and Paghman ranges. The more southerly of these, which is found between Jalalabad and Kabul, comprises metamorphic rocks associated with ruby-bearing crystalline limestone—a series recalling the

* C. A. McMahon : *Quarterly Journal, Geological Society*, Vol. LVI, 337 (1900).

† C. A. McMahon and W. H. Hudleston : *Geological Magazine*, Dec. IV, Vol. IX, 3, 49 (1902).

‡ H. H. Hayden : *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 31 (1904).

Archæan beds of the Peninsula—and a younger marine group in many respects resembling part of the Tibetan zone of the Himalaya. The marine group lies with marked unconformity on the metamorphic beds and is composed of limestones, probably in part representing the *Productus* limestone of the Salt Range and its analogues in the Himalaya and partly embracing the Lilang system of the Tibetan zone. The northern facies, which is well seen in Bamian, Saighan and the country to the north of the Afghan Hindu Kush, consists of limestones of Palæozoic age overlain by a volcanic series possibly partly younger Palæozoic and partly of Triassic age. This is covered by an extensive system of fresh-water beds with coal seams, * and containing fossil plants of Jurassic age. Neither the volcanic series nor the overlying Jurassic beds resemble any of the Mesozoic systems of the Himalaya, but are, on the other hand, apparently identical with the Mesozoic beds of Russian Turkistan;† hence during part of the Triassic and Jurassic periods these two areas formed a continuous land surface, and probably constituted the south-western coast of the Tethys. Above the Jurassic plant-bearing series is a mass of red conglomerate and sandstone, which is, however, only locally preserved, having been as a rule removed by denudation before the deposition of the next overlying rock group, the upper Cretaceous limestone. The latter extends all over Northern Afghanistan and is almost always markedly unconformable to underlying beds, a feature which indicates a great extension of the Tethys in later Cretaceous times, when the whole of Northern Afghanistan once more became submerged. This marine phase, however, was of only short duration, for evidence of the drying up of the sea is found in the beds of gypsum and rock-salt occurring in the older Tertiary rocks. Subsequently land plants and land shells appear, and all the great valleys of Eastern Afghanistan are now filled with deposits of sand and boulders analogous to, and possibly contemporaneous with, the Siwalik series of the outer Himalaya.

* C. L. Griesbach : *Records, Geological Survey of India*, Vol. XX, 93 (1887).

† J. B. Mushketoff : *Turkistan* (1886, 1906); G. Romanowski : *Geology of Turkistan* (1880-1890).

36

PAST HISTORY OF THE HIMALAYAN AREA.

We may now attempt to sketch roughly the past geological history of the Himalayan area. Our knowledge of the nature and distribution of the Archæan rocks is as yet too scanty to permit of any attempt to reconstruct the conditions prevailing at any part of that period and our history opens at the time when a shallow sea lay over Central and Northern India and extended into the Himalayan region, covering most of the area now lying on the Indian side of the axis of the present Great Himalayan range. In this were deposited beds of conglomerate, shale, sandstone and limestone, the materials for which were derived from the degradation of the Archæan rocks, exposed

in parts of what is now Peninsular India and also along
the Tibetan edge of the Himalayan zone between Assam
and Kashmir. The beds thus laid down are known as the Purana group in the Peninsular area * and include the Baxa, Jaunsar and Carbonaceous systems of the Himalaya. The connection of the one area with the other has still to be proved and the reference of the old unfossiliferous Himalayan sediments to the Purana group is consequently as yet only conjectural, but the conjecture has an air of probability which renders it for the moment the most suitable working hypothesis. Hence it is now generally believed that the Purana sea not only covered much of the Peninsula but also extended over what are known as the lesser ranges of the Himalaya. Whether it extended northwards beyond the Himalaya we are unable to say since the whole of the interior of Tibet is, geologically speaking, unknown, but there is evidence to show that land existed in the Himalaya at least during part of the Purana era, and the sea may therefore have been bounded on the north by a Tibetan continental area.

Recent work in China has revealed the presence there of a series of pre-Cambrian beds which may be the equivalents of our Indian Puranas, and the presence at or below the base of the Cambrian system of a boulder-bed of clearly glacial origin, gives us a possible clue to the true correlation of the Blaini boulder-slate of the Himalayan zone and suggests that the Purana sea extended to China.

Two marked periods of volcanic disturbance have left their records in these pre-Cambrian beds of the central part of the Himalaya. The first occurred at the close of the Jaunsar period, when the lower beds of this system emerged from the sea and were covered by sheets of lava and volcanic ash. Again subsidence set in and the disturbed and eroded beds were once more submerged and were covered unconformably by a thick calcareous deposit, the Deoban limestone.

* T. H. Holland: *Trans. Mining and Geol. Inst. of India*, Vol. I, 48 (1906):

The second period of volcanic activity occurred during the deposition of the beds of the Carbonaceous system and is marked by bands of volcanic ash and basalt, which are found at several horizons in the system, thus showing that volcanoes were active in this area throughout a period of considerable duration.

The next era of which we have a record in the Himalaya is that named by Sir Thomas Holland the *Dravidian*; it begins with the conglomerates and other shallow-water deposits of the Haimanta system and extends to the period of disturbance of upper Palæozoic age characterised by the Talchir boulder-bed of Peninsular India and the great outburst of volcanic activity in Kashmir.

The Haimanta, the oldest of the Dravidian systems, is characterised by deposits of detrital origin such as conglomerates, sandstones (quartzites) and slates, with only rare and insignificant beds of limestone at its upper limit. It is evident therefore that it was laid down in shallow water near a coast line and the absence of any post-Purana beds among the rocks of the Himalayan zone suggests that the present southern boundary of the Haimanta deposits marks approximately an original limit of deposition and consequently the southern shore of the sea in which the Haimantas were laid down. The relations of the Haimantas to the Purana rocks of the Himalayan zone have not yet been worked out and it is not known whether there is a gradual and conformable passage from the one into the other or whether the lower beds of the Haimantas are contemporaneous with the upper strata of the Puranas, nor is it possible to say at what period the Himalayan zone of Purana rocks first became a land-surface. The presence of rocks of the Haimanta system in Kumaun, Garhwal, Spiti and Kashmir proves that these areas at least were submerged, whilst during the latter part of the Haimanta period the sea extended also to the Salt Range of the Punjab where the Cambrian rocks contain a species of trilobite identical with one from the uppermost Haimantas of Spiti.* Westwards the same sea probably extended at least as far as the Hindu Kush and Afghanistan, but it was not connected with the Cambrian sea of Europe, for the fauna of the fossiliferous rocks of this age in the Himalaya has nothing in common with that of the European Cambrian. On the other hand, there are decided affinities between the Cambrian fossils of the Himalaya on the one hand and those of China and North America on the other, and this has been regarded as evidence of a sea connection between the Himalaya and America during late Haimanta (Middle Cambrian) times.

The latter part of the Haimanta period was marked by local disturbances in Spiti and probably also in Kashmir, and the presence of a conglomerate lying unconformably on the Middle Cambrian beds proves that the coast-line had moved temporarily northwards and the beds already deposited had emerged from the sea and undergone denudation. Normal conditions appear to have been soon restored throughout the Himalaya, but the absence from the Salt Range of any representatives of the post-Cambrian and pre-Talchir systems indicates that this range was now cut off from the Himalayan marine area and became a land-surface.

* F. Cowper Reed, quoted in *Records, Geological Survey of India*, Vol. XXXVI (1908).

The next geological epoch, the Muth, which approximately coincides with the Silurian (Ordovician and Gothlandian) of Europe, is remarkable for the great westerly extension of the Central Asian sea. The southern coast-line appears to have remained for a long period, at least until Lower Carboniferous times, much as it was after the Salt Range was cut off from the sea which covered the Himalayan area at the close of the Cambrian epoch, but the Tethys now encroached westwards and became linked up with the Palæozoic sea of Europe. Evidence of this is to be found in the character of the fossils of the representatives of the Upper Silurian, Devonian and Carboniferous systems in the Indian area, which bear a marked resemblance to those of the same systems in Europe, certain species being common to both areas. During the Devonian period the sea covered all the northern portion of the Himalayan area and extended eastwards into Burma, south-eastern Tibet and China. Westwards it appears to have extended through Kashmir, over what is now the Hindu Kush, into Afghanistan and northwards to the Pamir and the Tian Shan; its record is not very clear in the greater part of the Tibetan zone of the Himalaya, where fossils of Devonian age are scarce, having been found only at rare intervals, but there is no evidence of any break in the continuity of marine deposits between the beginning of the Muth (Silurian) period and the middle of the Carboniferous. The latter period, however, saw many changes along the southern coast of the Tethys and ushers in the next and latest era in the geological history of India, that named by Sir Thomas Holland the *Aryan*.

India now became definitely established as an integral part of that great continent of Gondwanaland, which extended to South Africa on the one side and Australia on the other and on which flourished the flora of *Glossopteris* and *Gangamopteris* familiar to us from the rocks of the Indian coal-fields. Below the beds in which these fossils occur, there is found in Australia, Africa and India a peculiar boulder-bed or tillite, which bears unmistakable evidence of having been deposited at a time when glacial conditions prevailed; the boulders found in it are faceted, polished and scratched whilst the rocks on which it lies are grooved and polished in a manner characteristic of the action of a glacier. This tillite, known as the Talchir boulder-bed, has not been proved to exist in the Himalaya, but is an important member of the stratigraphical series of the Salt Range, where its glacial origin has been proved beyond a doubt. On the Indian Peninsula it is usually regarded as of fresh-water origin, but in the Salt Range it is associated with marine beds, and would therefore appear to have been deposited in the sea. The materials of which the boulders are composed for the most part belong to a group of rocks now exposed in Rajputana, and it is therefore clear that, during the early Gondwana glacial period, Rajputana was a land-surface whence glaciers flowed northwards to deposit their imbedded boulders in the Salt Range sea, which was presumably a southern arm of the Tethys.

Whilst these changes were taking place in the Salt Range, Kashmir, which had formerly been covered by a shallow sea in which the shales and conglomerates of the Panjal system were deposited, had become the scene of great volcanic activity; masses of lava were poured out

Panjal volcanic phase in Kashmir.

and, solidifying, formed what we now know as the Panjal traps. These have been regarded as of submarine origin, but the evidence of this is not convincing; ashes certainly fell into the sea, where they were interstratified with marine limestones, as at Imsalwara to the west of the Wular lake. Elsewhere the lavas may have been poured out over a land-surface, and it is possible that at this period Southern Kashmir was an archipelago of volcanic islands.

At the close of the volcanic phase the peculiar *Gangamopteris* flora of Gondwana-land had spread to Southern Kashmir, which must therefore have become connected with the mainland. But the sea soon encroached again and the plant-bearing Gangamopteris beds were covered by the Zewan beds, typical marine deposits with fossils of upper Carboniferous age. These again pass upwards into the Permian Productus shales which are overlain by the fossiliferous limestones of the Lower Lilang system (Lower Trias); from the Gangamopteris beds upwards to the Lilang system there is no sign of any important break in continuity of the deposits, and it would therefore appear that the close of the Panjal volcanic period marks the beginning of an era of subsidence and uninterrupted deposition, which lasted from the middle of the Carboniferous epoch until early Tertiary times, and throughout the whole of which Kashmir lay beneath the waters of the Tethys.

In other parts of the Himalaya there is no evidence of violent disturbance having taken place during the volcanic period of Kashmir; in Spiti there was slow, but steady rise of the sea-floor, resulting in a gradual northerly displacement of the coast-line, and what had formerly been an area of comparatively deep water was converted into a shallow coastal platform or possibly an estuary, in the sands and muds of which the remains of plants carried down from the land became embedded. But the remainder of the Carboniferous epoch was a period of some instability, and is marked by oscillations of the sea-level. These, however, were for some time comparatively trifling, but, at the close of the Carboniferous period, a steady rise of the land and northward retreat of the sea set in; almost the whole of the Himalaya to the east of Kashmir

Subsequent tectonic disturbances in Spiti and Kumaun.

appears to have become a land-surface and remained such for a considerable length of time, long enough, in fact, for the removal by denudation of beds some thousands of feet in thickness. In parts of Spiti, in Kumaun, and in Garhwal, the whole of the deposits laid down during the Carboniferous and Devonian epochs, and even a great part of the Muth system, were removed before the land was resubmerged and the waters of the Tethys once more covered this part of the Himalaya.

It is interesting to note that these two periods of disturbance were not contemporaneous: that of Kashmir occurred at the end of the Dravidian era, while the Central Himalayan disturbance was of more recent date and is not reflected in any corresponding movement in Kashmir, having been probably of only local importance.

The earlier disturbance, however, belongs to a different category. It corresponded in time with the far-reaching changes which ushered in the Gondwana glacial epoch in India, Australia and South Africa. Recent work in Kashmir has led to the conclusion that these changes occurred

The world-wide extension of the earlier (Panjal) disturbance.

towards the middle of the Carboniferous period,* a time when marked changes in the distribution of land and sea began to take place in many parts of the world. Throughout Asia it is characterised by a great extension of the sea and the consequent overlap of marine deposits of Middle Carboniferous age upon older beds. Evidence of the former presence of this sea can be found in the Salt Range,† in S. E. Afghanistan and the neighbourhood of the Khyber,‡ in Baluchistan,§ in Northern and Western Afghanistan,|| Persia,¶ Kashmir,** the Central†† and Eastern Himalaya;‡‡ eastward it extended into China and westward into Europe.§§

Of the northerly extension of the sea beyond the Indo-Tibetan frontier we as yet know nothing, but among the exotic blocks of Kumaun, already referred to (*supra*, p. 238), are masses of limestone containing a fauna similar to that of the *Productus* limestone of the Salt Range, and we therefore conclude that Ngari Khorsum at least was submerged at this period.

In this connection we may draw attention to the important and interesting work recently carried out in China by Messrs. Bailey Willis, E. Blackwelder, and R. H. Sargent, the results of which have been published by the Carnegie Institution of Washington.|| In the second volume Mr. Willis discusses the distribution of land and sea in Eastern and Central Asia during past geological ages, and assumes that, throughout the whole

Extension of the Dravidian Tethys over Tibet.

of the Palæozoic era, Tibet was a continental area, which he designates *Isle Tibet*. Having regard to our present ignorance of the geology of the greater part of Tibet, we can offer no direct observations bearing on this question; but if we turn to north-eastern Ladak, we find Palæozoic rocks exposed in the neighbourhood of Changchenmo and Pangong Lake, and if, as appears to be the case, the trend of these beds is the same as that of the rest of the Tibetan zone in Kashmir, Spiti and Kumaun, we should expect to find them well to the north of the head-waters of the Indus and the Brahmaputra in Western and Central Tibet. We are, therefore, inclined to believe that Palæozoic beds do occur in the great lake-basin of Central Tibet. They may possibly be hidden by the younger (Mesozoic) deposits to which we shall refer subsequently, but it may reasonably be expected that they will be found to crop out here and there, and thus prove that the sea in which the Dravidian (Palæozoic) rocks of the Tibetan zone were laid down was not, as has been assumed, merely a strait connecting Eastern and Western Asia, but extended northwards over a great part of Tibet.

* *Records, Geological Survey of India*, Vol. XXXVI, 23 (1907).

† *Manual of the Geology of India*, 2nd edition, 123 (1893).

‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXVIII, 108 (1900).

§ *General Report, Geological Survey of India*, for 1901-02, 31 (1902).

|| C. L. Griesbach: *Records, Geological Survey of India*, Vol. XX, 96 (1887).

¶ J. de Morgan: *Mission Scientifique en Perse*, III (1905).

** R. Lydekker: *Memoirs, Geological Survey of India*, Vol. XXII (1883).

†† H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1 (1904).

‡‡ C. Diener: *Records, Geological Survey of India*, Vol. XXXII, 189 (1905).

§§ Th. Tschernyschew: *Mem. Com. Geol., St. Petersburg*, XVI, No. 2 (1902), and *Records, Geological Survey of India*, Vol. XXXI, 111 (1904).

Research in China (1907).

Towards the close of the Palæozoic era, the Central Asian sea, which had extended from India to China on the one side and Europe on the other, gradually began to recede westwards, and in Triassic times much of China had become a land-surface. The sea, however, still lay over the Himalaya, and its connection with the European sea is proved by the large number of identical species of marine fossils found in the Triassic deposits of the Alps and the Himalaya. During the earlier part of the Triassic epoch the Salt Range formed part of the Tethys, which also covered Kashmir and Hazara, and appears to have extended into Eastern Afghanistan. Later on, connection with the whole of China, except the southern part, appears to have been cut off, and in Upper Triassic times the Salt Range also became a land-surface, but the sea extended from Eastern Afghanistan into Baluchistan, and also from Kashmir through the Pamir into Bokhara. These changes did not affect the Himalayan area and Kashmir, both of which remained submerged throughout the whole of the Mesozoic era.

During the Jurassic period great changes in the distribution of land and sea took place in Asia. The continental phase, indications of which are first to be found at the close of the Palæozoic era, became largely developed, and there arose on the north a great continent named by Suess "Angaraland,"* which was analogous to Gondwanaland on the south, and the site of which is now marked by a series of fresh-water beds and coal-seams, comparable to the Gondwanas of India. Communication between the Himalayan Tethys and the Mesozoic sea of Europe remained open, and the whole of Southern Tibet was submerged. At the same time the sea extended once more to the Salt Range and thence through Baluchistan and Southern Afghanistan to Persia. Northern Afghanistan, however, became dry land, on which flourished a flora similar to that of Angaraland at the same period. That the latter part of the Jurassic epoch was characterised by the gradual shallowing of the Himalayan and Tibetan sea is proved by the nature of the uppermost Jurassic deposits, the Spiti shales, which are composed of fine detrital sediments alternating here and there with beds of coarser material.

Similar conditions prevailed for the most part during early Cretaceous times, but in the latter part of the period a great extension of the sea took place and many areas that had previously been land became submerged. Connection, through Northern Africa and North-Western India (Baluchistan and Afghanistan), between the Mediterranean of Europe and the sea of Western India was now thoroughly established, and its progress is seen in the overlap of the upper Cretaceous beds over older formations which had been subjected to sub-aërial erosion during Jurassic and early Cretaceous times. The Cretaceous sea extended along the whole of the site of what we now term the Tibetan zone of sedimentary rocks and probably stretched far to the north over much of Tibet. Eastern Tibet and China, however, were now a continental area.

* *La Face de la Terre*, III, 27 (1902).

This "transgression" of the upper Cretaceous sea indicates a widely extended subsidence of the land, affecting north-western India, Afghanistan, Western Asia and probably much of Tibet. On the Indo-Tibetan frontier, however, there was no marked movement of subsidence, for the Cretaceous deposits of the Tibetan zone of the Himalaya are largely characterised by sediments such as are laid down in the neighbourhood of a coast-line. Associated with these on the southern frontier of Ngari Khorsum are beds of tuff, which indicate the presence of volcanoes at no great distance and prepare us for the volcanic disturbances that ushered in the great epoch of mountain-building which produced the mighty ranges of the Himalayan chain.

We have already seen that the Cretaceous sea lay over a great part of Tibet and extended as far south as the northern frontier of Sikkim. At the same time the Shillong Plateau was under water and was part of the floor of an ocean which extended along what is now the east coast of the Indian Peninsula but was then the submerged edge of Gondwanaland which, at the beginning of the Cretaceous period, still survived as a continent, though probably much reduced in size; this continent, however, appears to have begun to break up during the latter part of the period and in upper Cretaceous (senonian) times direct connection was established between the North African sea and the Pacific, through a strait separating India from Madagascar.

It is possible that there may have also been a narrow and shallow arm of the sea running through that curious depression which is now filled by the Indo-Gangetic alluvium. That in early Tertiary times the western sea flowed over what is now the south-western foot of the Himalaya almost up to the meridian of Naini Tal is clear from the presence of nummulitic limestone all along that belt, and in the Tal beds there is some indication of a shallow arm having reached Garhwal at a much earlier period, probably sometime during the Jurassic epoch;* it would not, therefore, be surprising to find that the great upper Cretaceous transgression also affected this area. The absence of any Cretaceous rocks in this part of the Himalaya is certainly an argument against this supposition, but they may either have been completely removed by denudation at a subsequent period or may be merely hidden by the alluvium.

There is at present no evidence that the arm of the Pacific in which the Cretaceous beds of Burma and Assam were deposited was connected with the Tibetan sea; this can only be decided by exploration in the unsurveyed country around the head-waters of the Lohit Brahmaputra and the Irrawaddy. If there was no connection between the two oceans, the Eastern Himalaya must have been at this time either a narrow peninsula running out from the Chinese mainland or else an isthmus connecting that continental area with Gondwanaland.

Several periods of volcanic activity have left their records in the Himalayan area. Of these, two occurred during Purana times and a third at the middle of the Carboniferous period; another has been ascribed † to the upper Cretaceous epoch.

* C. S. Middlemiss: *Records, Geological Survey of India*, Vol. XX, 26 (1887).

† A von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902).

a period marked in the Peninsula by the great outpouring of lava which constitutes the

Periods of volcanic activity.

Deccan trap. From this time onward there was a steady retreat of the sea from Tibet and the adjacent portions of the Himalaya; there were, no doubt, local oscillations of the coast-line as indicated, for instance, by the overlap of the nummulitic beds of Kashmir over older fresh-water deposits, but by the end of the eocene period, Tibet and the Himalaya had finally become dry land, and the western sea had been driven back to Sind and Baluchistan. This last phase in the marine history of the Himalayan area was accompanied throughout the whole Indo-Tibetan region* by great volcanic activity, which was no doubt intimately connected with the crustal disturbances to which the origin of the Himalaya is to be attributed. The igneous phase began with the intrusion of masses of granite into the sedimentary deposits of the Tibetan zone; subsequently there were outbursts of basic lavas which flowed over parts of Ladak, Ngari Khorsum and western Tibet, whilst dykes of basalt and allied rocks were formed by the injection of the basic magma into fissures both in the sedimentary beds and in the granite.

Volcanic activity seems to have been most intense in the neighbourhood of Lake Manasarowar, which has more than once been an area of special disturbance, and the comparatively recent change in the direction of flow of the upper Brahmaputra, to which attention has been drawn in a previous chapter (*supra*, p. 155), is an indication of elevation having occurred in this area at no very distant date in the past (*supra*, p. 178).

Although the volcano of Barren Island in the Bay of Bengal was active during the past century,† and other volcanoes in Eastern Persia on the immediate confines of Afghanistan are not yet extinct,‡ there is no indication of recent volcanic activity in the Himalayan region. In Central Tibet Mr. Littledale records a large number of volcanoes, none of which, however, appears to have been active at the time of his visit.§

SUMMARY.

If, now, we endeavour to summarise the geological history of the Himalayan area, we find that at the earliest time of which we have any record, it was part of the floor of the Purana sea, which stretched over much of what is now the Indian Peninsula; owing to elevation, this area subsequently became dry land and the sea retired to the north, where it remained throughout the whole period covered by historical geology from early Cambrian times until the middle of the Tertiary epoch; local oscillations occurred from time to time, the sea retreating northwards but again returning to cover the recently eroded land with marine deposits. Its southern shores, however, never

* A. von Krafft: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 3 (1902); H. H. Hayden: *Memoirs, Geological Survey of India*, XXXVI, pts. 1 and 2.

† F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. XXI, pt. 4 (1885).

‡ E. Vredenburg, *Memoirs, Geological Survey of India*, Vol. XXXI, pt. 2 (1901).

§ St. G. R. Littledale: *Geographical Journal*, Vol. VII, 453 (1896). For numerous references to recent volcanoes in the Kuen Lun range see Suess, *La Face de la Terre*, III, 288 (1902).

seem to have moved very far one way or the other, and that part of the Himalayan area lying on the Indian side of the line of great peaks may be regarded as approximately the northern coast of Gondwanaland. It is probable, therefore, that since very early times the greater part of the Himalaya has been a land-surface.

Towards the end of the Mesozoic era the sea encroached both from the west and from the east and either completely or partly cut off the Himalayan area from Gondwanaland.

The general history of the Himalayan area may be tabulated as under :—

PURANA ERA.

Much of Peninsular India and the Himalayan area covered by a sea which may have extended to China. Volcanic activity during Jaunsar and Carbonaceous periods. Blaini glacial epoch.

DRAVIDIAN ERA.

Emergence and conversion into dry land of Peninsular India and the southern parts of the Himalayan area.

Haimanta period.—Submergence of Salt Range area and Tibetan zone of Himalayan area—probably also Tibet—beneath a sea, which extended to China and possibly to North America.

Muth and Lower Kanawar periods.—Salt Range area became dry land but sea still spread over Tibetan zone eastwards to China and towards the end of the period westwards to the European ocean. Panjal volcanic period in Kashmir.

ARYAN ERA.

Upper Kanawar and Kuling periods.—Gondwana glacial epoch in India, Africa and Australia. Extension of continental conditions to Kashmir, followed by re-submergence affecting Salt Range area, Kashmir and the whole Tibetan zone ; local oscillations of land and sea in Spiti and Kumaun.

Lilang period.—Marine conditions completely established throughout Tibetan zone ; re-emergence of Salt Range area. The Tethys covered much of Central Asia and was continuous with the Triassic sea of Europe.

Jurassic period.—Gradual rise of land and shallowing of Tethys throughout the Tibetan zone. North-East Afghanistan a land surface, probably a part of Angaraland.

Cretaceous period.—Further rise of land in Tibetan zone, with extension of sea ("transgression") to Afghanistan and Assam. Volcanic disturbances in Ngari Khorsum.

Tertiary epoch.—Period of mountain-building : final emergence of Himalaya and Tibet and disappearance of the Tethys. Volcanic activity during eocene period.

37

AGE OF THE HIMALAYA.

There is no evidence to show that the Himalaya, as a great mountain range, are older than the latter part of the eocene period. There are undoubtedly signs of former periods of considerable folding; thus, the Purana rocks were folded and compressed during the earth-movements that resulted in the birth of Gondwanaland, but the Himalayan area then became the northern coast of the new continent and was not necessarily a mountain range. Towards the end of the Haimanta (Cambrian) period local folding again took place, for we find the (Ordovician) conglomerates of the Muth system in Spiti lying on the eroded edges of folded beds of Middle Cambrian age. After this, no tectonic movements of great intensity seem to have occurred until the last upheaval of the Himalaya and Tibet in Tertiary times. Movements there undoubtedly were, as, for instance, during the Carboniferous period when marine sediments were raised up, denuded and again depressed beneath the sea, but the parallelism to these older beds of the younger deposits subsequently laid down on them shows that the former underwent no contortion, but were merely subjected to a gentle uplift without violent crustal compression. Thus we have no evidence of mountain building in the Himalayan region before the Tertiary period. The movement which was so pronounced during this latter period probably began in late Cretaceous times and continued throughout the eocene and Middle Tertiary periods. That it was still active during the pliocene epoch is proved by the great series of overthrusts along the outer foot of the Himalaya, the origin and history of which have been so admirably traced out by Mr. C. S. Middlemiss.*

The movements which affected the Siwalik (pliocene) deposits of the outer Himalaya were not confined to the neighbourhood of the Indo-Gangetic plain, but extended to such widely separated regions as Afghanistan and Ngari Khorsum. In the former area all the great river valleys of Eastern Afghanistan are filled with beds of sand-rock and conglomerate which are exactly similar to the Siwalik deposits of the Indian "duns," † and have, like them, undergone much folding and tilting. In Ngari Khorsum (Hundes) similar deposits were observed by Mr. Griesbach in the Nukchung valley, ‡ and these also show signs of considerable disturbance. As the age of these deposits is pliocene, it is clear that even at the end of this epoch the crustal movement, to which the Himalaya owe their origin as a mountain range, was still active.

* *Memoirs, Geological Survey of India*, Vol. XXIV, pt. 2 (1890).

† *Dun* is the Indian term for the narrow longitudinal valleys lying between the outer Siwalik ranges and the higher hills of the Lesser Himalayan ranges (*supra*, p. 85).

‡ *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

In the next geological period, however, the Himalaya appear to have reached a stage of comparative quiescence. In the upper valley of the Sutlej in Ngari Khorsum there are vast deposits of boulders, sand and clay, in which occur remains of mammals * regarded by Mr. Lydekker as of pleistocene age.† The exact origin of these deposits has not been definitely ascertained, but they are now generally regarded as fluviatile, though possibly also in part lacustrine.‡ They lie unconformably on the tilted pliocene sandstones, but are themselves almost perfectly horizontal, thus showing that, since their deposition, no violent disturbance has affected this part of the Himalayan region.

In the valley of Kashmir, very similar deposits occur, where they are known under the name of *Karewa*. These have been described from time to time by various observers as of lacustrine origin, but from a detailed study of them in recent years, Mr. R. D. Oldham has concluded that their mode of origin was similar to that of the alluvial deposits in process of formation in the same valley at the present day.§

If we are right in regarding the ossiferous deposits of Ngari Khorsum and the Karewas of Kashmir as of pleistocene age, we are led to infer that the general features of the Himalaya were at that period much as they are at the present day. We have already seen (*supra*, p. 210) that the main drainage lines date back as far as the pliocene epoch, and that the rivers which brought down the sand and boulders from the mountains to build up the Siwaliks of the duns and of Hundes were the direct ancestors of our modern Sutlej and Ganges.

Of the topography of the Himalayan area before this period we as yet know practically nothing, but it is clear that the old coast-line of Gondwanaland cannot have been very far from the present southern boundary of the Tibetan zone of sediments, and detailed surveys will very possibly reveal the sites of pre-pliocene rivers, as indicated by the coastal or estuarine deposits laid down at their mouths. During the Palæozoic and much of the Mesozoic periods, when the Indian Peninsula and the zone of oldest rocks of the Himalaya formed part of Gondwanaland, rivers must have flowed northwards from India to the Tethys, and we have already noticed the evidence of the direction of drainage afforded by the pebbles of the Salt Range boulder-bed (*supra*, p. 251). In the distant future, when the geology of the Himalaya is known as intimately as that of England and parts of continental Europe at the present day, the presence of deposits like the Gangamopteris beds of Kashmir may enable us to locate, among the sedimentary beds of the Tibetan

* R. Strachey: *Quarterly Journal, Geological Society*, Vol. VII, 292 (1851); C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XXIII (1891).

† *Records, Geological Survey of India*, Vol. XIV, 178 (1881).

‡ *Manual of the Geology of India*, 2nd edition, 422 (1893).

§ *Records, Geological Survey of India*, Vol. XXI, 157 (1888); T. H. Holland, *Records, Geological Survey of India*, Vol. XXXII, 152 (1905).

zone, the sites of some of the estuaries of this old drainage system, but all traces of its river-valleys through the central zone must have long since been removed by the subsequent processes of denudation, whilst the new drainage system, which has gradually arisen in a reverse direction, has replaced and obliterated the old.*

Of the present river-valleys of the Himalaya, one at least can be shown to have existed as early as in the eocene period. In the Upper Indus valley in Kashmir are beds of either fresh-water or estuarine origin, which are of eocene age. They form a long and narrow strip in the present valley and mark the position of an old river-valley or of an estuary, which was apparently connected with the Tibetan portion of the Tethys.

Subsequent oscillations of the relative level of land and sea led to these fresh-water beds being covered by marine deposits containing nummulites, but the latest phase in the elevation of this area has resulted in the removal by denudation of the cap of younger beds and the old valley has been thus once more exposed to view. The presence of a valley along approximately the same line at two periods separated by such a great interval of time shows that its origin is not due to mere erosion, but must be attributed to structural causes, connected with the folding of the earth's crust, and producing a depression which was first outlined at least as long ago as the eocene period. This, again, is a further indication that the movements which finally resulted in the upheaval of the Himalaya were already operative at that period.

Although the practically undisturbed condition of the pleistocene beds of Ngari Khorsum and of the Karewas of Kashmir leads us to suppose that there have been no violent disturbances in the Himalayan region since their deposition, many facts suggest that the apparent quiescence is only comparative and that movement tending to a further rise of the Himalaya is now in progress. That movement has not ceased is evident from the frequent earthquakes occurring in the Himalaya and Afghanistan, and such catastrophes as the Kashmir earthquake of 1885,† those of Shillong in 1897‡ and of Kangra in 1905§ forcibly remind us that the Himalayan region is by no means at rest.||

These, however, do not serve to give us any indication of the direction of movement, which we can at present deduce only indirectly from other phenomena. Amongst these may be mentioned the observations already referred to (*supra*, p. 204) in connection with the apparent progressive desiccation of the Tibetan lakes, a phenomenon which has been regarded as due to the rise of the Himalaya and consequent cutting off from Tibet of the moisture-laden monsoon winds. Evidence of such rise being now in progress is also to be found in the

* Since the above was written, a paper has been published by Mr. R. D. Oldham, on "The Valleys of the Himalayas," *Geographical Journal*, XXX, 512 (1907), in which he also refers to such a pre-existing drainage system.

† E. J. Jones : *Records, Geological Survey of India*, Vol. XVIII, 221 (1885).

‡ R. D. Oldham : *Memoirs, Geological Survey of India*, Vol. XXIX (1899), XXX (1901).

§ C. S. Middlemiss : *Records, Geological Survey of India*, Vol. XXXII, 258 (1905).

|| For a complete list of Indian earthquakes up to the end of the year 1869, see T. Oldham : *Memoirs, Geological Survey of India*, Vol. XIX, pt. 3 (1883).

present condition of the chief Himalayan rivers. The general tendency of a river rising in a mountainous region and flowing out on to a plain is to remove material from its upper reaches in the mountains, where its gradient is steep, and deposit it on the plains at their foot; as this process proceeds, the river gradually cuts down its channel, working most

(3) by rejuvenation of the streams. rapidly in the higher regions where its gradient is naturally steeper and less rapidly lower down. Where the gradient is steep and the current rapid, the water carries with it large quantities of material such as boulders, pebbles and sand; where, however, the current is less rapid in the lower reaches, its force is insufficient to carry the whole of its load and some or all of it is deposited. The tendency of the river is therefore to remove material from its upper reaches and deposit it in the lower, thus producing a flattening of its gradient throughout, in consequence of which the depositing section of the stream gradually creeps further and further back towards its head. If, during this process, the land round the head-waters of the stream undergoes a movement of elevation, the gradient and consequently the erosive power of the stream will be increased and the water begin to cut a channel through the deposits which had accumulated in the lower valleys. This phenomenon is known as the rejuvenation of a stream.

At the present day the great Himalayan rivers are not depositing in their lower reaches, except near the points at which they debouch from the mountains and consequently are not in that stage of equilibrium which characterises an old river. On the other hand, their valleys are cut through horizontal deposits of boulders and river-gravels, which can be seen to extend many hundreds of feet above the present stream-bed.* It is clear, therefore, that where the rivers are now in the active stage of abrading, they were once depositing streams and filled their rocky valleys with the sands and gravels through which they have since re-excavated their channels. They have, therefore, undergone rejuvenation presumably due to uplift of the highlands amongst which they rise.

When this uplift began, we are not yet in a position to say since we have at present no evidence of the age of most of these old river-deposits.

Date of this movement.

It has already been pointed out that the ossiferous beds of Hundes are probably of pleistocene age, whilst the Karewas of Kashmir have been attributed to the same period; the other high-level alluvial deposits found in the Sutlej and the Indus may be of the same age or may be of later date, but we are justified in assuming that during the pleistocene epoch, and probably for some little time afterwards, little or no movement took place in the Himalaya, and the rivers gradually tended to assume a state of equilibrium, which, however, was subsequently disturbed by further elevation of the higher ranges and the Tibetan region, resulting in increase of gradient and consequent rejuvenation of the streams, and the present steep gradients of most of the Himalayan rivers lead us to conclude that uplift is either still in progress or has only quite recently ceased.

* H. B. Medlicott: *Records, Geological Survey of India*, Vol. IX, 55 (1870); R. Lydekker: *Memoirs, Geological Survey of India*, Vol. XXII (1883).

Similar evidence of recent elevation of the higher ranges of the Himalaya has been deduced by Mr. R. D. Oldham from the manner in which many of the southward-flowing streams are rapidly cutting back into the catchment areas and capturing the drainage of the Tibetan rivers on the north.* Striking examples of this are furnished by the Ganges,† the Tista‡ and the Sind river in Kashmir.§

A most instructive example of this rapid cutting back of the southward-flowing streams on the southern flanks of Kinchinjunga in Sikkim (2) by "hanging valleys" in Sikkim: has been described by Prof. Garwood.|| Here the Rathong Chu ¶ and Praig Chu, feeders of the great Rangit, have cut back their heads so rapidly that they have actually truncated and captured what was formerly an important eastward-flowing tributary of the Tista. So rapid has been the work of these two streams that they have cut deep chasms or gorges across the old valley, with the result that the remnant of this former tributary of the Tista is now only a small stream, which "occupies a nearly level upland glen, three miles in length and some 2,000 feet above the floor of the Rathong Chu, and this elevation is maintained nearly to its mouth, whence it empties itself by precipitous cascades into the valley beneath." This rapid head erosion and "piracy" on the part of the Rathong Chu is ascribed to recent elevation of the Kinchinjunga massif lying to the north; such elevation would increase the gradient and consequently the erosive power of the Rathong Chu while not affecting that of the eastward-flowing stream, which would be merely tilted sideways.** Here we see that local uplift will account not only for the formation of a deep gorge on the flank of a range, but also to some extent for those curious side valleys which, as Prof. Garwood graphically expresses it, appear to be suspended in mid air high above the level of the main valley, which they join in a sheer precipice. The difference of level between these "hanging" valleys and the main stream is thus due partly to more rapid erosion of the channel of the latter, through a steepening of gradient attributable to uplift of the mountains at its head, but partly, in Prof. Garwood's opinion, to the recent occupation of the hanging valleys by glaciers which have protected them from the effects of river erosion.

Such uplift has also been regarded as a contributory cause of the deep and narrow gorges to be seen in so many of the Himalayan rivers. In a previous part (*supra*, p. 184), reference has already been made to these gorges and various possible modes of origin suggested. Two of these are of

* *Journal, Manchester Geographical Society*, Vol. IX, 112 (1893).

† *Ibid.*

‡ H. H. Hayden : *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 2 (1907).

§ R. D. Oldham : *Records, Geological Survey of India*, Vol. XXXI, 142 (1904).

|| "The Geological Structure and Physical Features of Sikkim" in D. W. Freshfield's *Round Kangchenjunga*, 296 (1903).

¶ Chu=stream or river (Tibetan).

** *Op. cit.* 298; see also "Notes on a Map of the Glaciers of Kinchinjunga" by the same author in *Geographical Journal*, Vol. XX, 13 (1902).

special interest, and are regarded as embodying the main principles involved. They are—

- (1) that the Himalayan drainage system had been established before the ranges, across which the rivers now cut, had become axes of special elevation, and that when elevation finally took place its rate was not so great as to interrupt the course of the river, which was therefore able to keep its channel open by abrasion across the rising range;
- (2) that the old rivers have been dammed by the rising ranges and their valleys thus become lakes, the waters of which eventually overflowed and carved out gorges.

The first of these theories, which we owe to Mr. H. B. Medlicott,* has been applied with striking success by Mr. R. D. Oldham to the river-valleys of the Himalaya and neighbouring areas. In the comparatively young mountains of Baluchistan, which was still under the sea after the Himalaya had become dry land, he has followed out the earlier stages in the process of the formation of gorges and has subsequently extended these principles to the Himalaya themselves.† He has suggested that the present gorges of the Indus and the Brahmaputra lie along the alignment of valleys which were defined at the time when the upheaval of the Himalaya first began and when a pair of longitudinal valleys was established along the northern face of the rising mass, round the extremities of which the drainage escaped towards the south. This assumption is borne out by the observations of Mr. Medlicott, who has shown that the great Himalayan rivers are “antecedent” and that their debouchures in Siwalik times were where they are at the present day (*supra*, p. 210), whilst the nature of the Indus valley Tertiary deposits is evidence of the existence of a structural valley along the line of the Indus at a very early date (*supra*, p. 260).

The second theory has been advanced by Colonel Burrard to explain the origin of the gorge of the Brahmaputra.‡ He has suggested that an old river-valley, having become blocked by the rise of a mountain range, has been filled by a lake, the overflow from which has subsequently cut a channel resulting in the present gorge. Such a diversion of drainage has been shown by Mr. R. D. Oldham to have occurred in one instance in Baluchistan,§ but in this case there is no tendency for the new channel to become a gorge. The water, where it issued from a lake, would hold no sediment and would consequently have practically no abrasive power, hence, except in areas of extreme aridity, the sides of the outlet valley would be worn away by atmospheric denudation concurrently with the excavation of the new channel, and the valley would have gently sloping, rather than precipitous, sides.

There are several other difficulties in the way of the application of this process to the Himalayan gorges. In the first place, we should expect to find well-marked lake

* *Manual of the Geology of India*. 1st edition. 676 (1879).

† *Geographical Journal*, Vol. III, 169 (1894).

‡ *Ann. Rep., Board of Scientific Advice for India*. 1905-06, p. 67; also *supra*, part III, p. 85.

§ *Records, Geological Survey of India*, Vol. XXV, 28 (1892).

deposits in the basins above the gorges. These, however, have nowhere been recognised; the previously accepted views of the lacustrine origin of the Karewas of Kashmir have been recently disputed,* whilst the description given by the late Sir Richard Strachey of the pleistocene deposits of the Upper Sutlej valley† points to an origin in part, if not entirely, fluvial.

On the other hand, basins of this kind filled with fluvial deposits, and in some cases even holding lakes, are commonly found above gorges in almost all parts of the world, but it can usually be shown that they are due to the obstruction caused by hard bands of rock running across the valley. Thus, in the case of the Sutlej, the stream after passing through the sedimentary beds of Hundes encounters the hard granite of the great Himalayan range; its rate of erosion is retarded, and, while slowly wearing its way down into a narrow trough in the hard rock, it works also laterally in the softer beds, and so produces a broad basin above, in which alluvial deposits accumulate, and a gorge or "narrows" below.‡ Thus the gorges have been developed concurrently with the open basins behind the ranges rather than after, and as a consequence of the damming of, these.

The two hypotheses above quoted are mutually conflicting, but so little is yet known of the actual conditions of the Himalayan rivers that it is desirable to keep both in view. One fact, however, is clear, namely, that until systematic observations have been made of most of the great Himalayan rivers on the lines of the admirable work of Mr. R. D. Oldham in the Sind valley in Kashmir§ and of Prof. Garwood in Sikkim,|| we can make no advance in India in this most fascinating branch of historical research, the history of the surface features of the earth.

* *Supra*, p. 259; also Ellsworth Huntington: *The Pulse of Asia*, 22 (1907).

† *Quarterly Journal, Geological Society*, Vol. VII, 306 (1851).

‡ For details as to these processes see Sir A. Geikie: *The Scenery of Scotland* (1901); also Chamberlain and Salisbury: *Geology, Processes and their results* (1905).

§ *Records, Geological Survey of India*, XXXI, 142 (1904).

|| *Quarterly Journal, Geological Society*, Vol. LVIII, 703 (1902); *Geographical Journal*, XX, 13 (1902); *Appendix to D. W. Freshfield's Round Kangchenjunga* (1903).

38

ECONOMIC GEOLOGY OF THE HIMALAYA.

The Himalayan region is strikingly poor in minerals of economic value, there being only three industries which can be said to be established on a commercial basis; these are the salt and the slate quarries in Kangra district and the sapphire mines of Kashmir.

The salt quarries are situated at Guma and Drang in Mandi State; they are at present only of local importance, the output in 1906 being about 3,600 tons.*

Salt.

The Kangra slate quarries, which are at Kanyara, have been worked with considerable success for some years past. The rock is not a true clay slate, but is sufficiently fissile for the production of slabs and roofing-slates.†

Slate.

The sapphire mines, which are situated near Padar in Kishtwar, were first opened nearly 30 years ago, but after being worked for a few years were closed on account of diminution of output.‡ Recently, however, the industry has been successfully revived, the output being valued at £1,327 in 1906§ and £3,144 in 1907.||

Sapphire.

The other minerals found in the Himalayan region include: borax, coal, gold, gypsum, sulphur and ores of antimony, arsenic, copper, iron and lead.

Borax is found in Ladak, where it is obtained as an efflorescence from the surface of the alluvium of the Puga valley. The superficial coating is scraped up and boiled with water in coppers; the resulting brine is then cooled in small pits, when the borax crystallises out. The production at Puga is quite insignificant, almost the whole supply of borax brought into India being imported from Central and Western Tibet.

Borax.

The chief occurrences of coal in the Himalaya are among the Gondwana rocks of the Darjeeling Terai and Assam Duars and in the Tertiary beds of Jammu in Kashmir.

Coal.

As already pointed out (*supra*, p. 216), the Gondwana coal is usually too crushed to be of commercial value and such attempts as have hitherto been made to work it have not met with success.

The coal of Jammu occurs in a belt of Tertiary rocks to the north of the town of Jammu and comprises a number of fields known as the Ladda, Sangar Marg, Mehowgala, Siro valley, Kalakot and Lodhra coal-fields.

* T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 85 (1905); XXXVI, 80 (1907).

† T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 114 (1905).

‡ T. D. LaTouche: *Records, Geological Survey of India*, Vol. XXIII, 59 (1890).

§ T. H. Holland: *Records, Geological Survey of India*, Vol. XXXVI, 79 (1907).

|| T. H. Holland: *Records, Geological Survey of India*, Vol. XXXVII, 82 (1908).

The seams are highly inclined and their thickness is very variable. The coal is much crushed and usually contains a high percentage of ash.* Experiments recently made, with a view to testing the suitability of the coal for the manufacture of briquettes, did not give favourable results and the prospects of the development of these fields as a profitable undertaking are not promising.†

Another small coal-field occurs further to the north-west in the Kotli tahsil at Dandli, but the prospects here are even less promising.‡ Coal also occurs in the Nummulitic series in Hazara, but its quality is poor and the thickness of the seams very variable.§

Reference has already been made to the small patches of lignite occurring in the sandstones of the Siwalik series in the Sub-Himalayan zone (*supra*, p. 210). These have often given rise to expectations, always foredoomed to disappointment, of the discovery of workable coal-seams.

Gold is found in small quantities in the gravels of almost all the chief rivers of the Himalaya|| and its recovery provides occupation for the local inhabitants during the winter, when agricultural work is at a standstill.

In the Indus and its tributaries, and in the Sutlej, washing by means of primitive cradles is carried on to a considerable extent, but the results are at present too insignificant to raise this intermittent occupation to the status of a regular industry.

In the Eastern Himalaya, the gravels of the Brahmaputra and neighbouring rivers have long been known to be auriferous,¶ but so far no serious attempt has been made to exploit them on modern principles.

In Tibet, the gold fields of Rudok and Thok Jalung have been worked from very early antiquity and Herodotus' reference to the gold-digging ants, with the many ingenious commentaries to which it gave rise, is no doubt familiar to everyone.** The output of the Tibetan fields, however, is quite unknown, a circumstance to which the many stories of their fabulous wealth are no doubt to be attributed.

Gold is also found in Afghanistan, but what was formerly the most productive mine in the country, that of Kandahar, has long been closed owing to the miners having lost the vein.††

Gypsum occurs in thick beds, as the product of the alteration of limestone, in lower Spiti, at a short distance above the junction of the Spiti and Sutlej rivers. Although the quantity available is very large and the quality high, the locality is too far from markets and too inaccessible to offer any prospects of remunerative exploitation of the deposits.‡‡

* R. R. Simpson: *Memoirs, Geological Survey of India*, Vol. XXXII, pt. 4 (1904).

† T. H. Holland: *Records, Geological Survey of India*, Vol. XXXII, 137 (1905).

‡ C. M. P. Wright: *Records, Geological Survey of India*, Vol. XXXIV, 37 (1906).

§ C. S. Middlemiss: *Memoirs, Geological Survey of India*, Vol. XXVI (1896).

|| V. Ball: *Manual of the Geology of India*, pt. 3 (1881).

¶ J. M. MacLaren: *Records, Geological Survey of India*, Vol. XXXI, 205 (1904).

** For literature on the subject see *Manual of the Geology of India*, pt. 3, Art. *Gold* (1891).

†† C. L. Griesbach: *Memoirs, Geological Survey of India*, Vol. XVIII, pt. 1, 56 (1881).

‡‡ H. H. Hayden: *Memoirs, Geological Survey of India*, Vol. XXXVI, pt. 1, 101 (1904).

Sulphur is found at Puga in Ladak, where it is deposited from hot springs. The quantity is small and the occurrence of little or no economic importance.*

Sulphur.

Sulphide of antimony (stibnite) occurs in some quantity near the Shigri glacier in the valley of the Chandra river in Lahaul. The locality has long been known,† but no serious attempt had been made to work it until quite recently, when prospecting operations were undertaken and a mining lease obtained with a view to its exploitation. No information is as yet available as to the result of the operations.

Antimony.

Orpiment, the yellow sulphide of arsenic, is found in Chitral, Hunza and Kumaun. In Chitral it has been mined for a long period, but the production has fallen off in recent years, having dropped from a little under thirty tons in 1904-05 to less than ten in 1905-1906.

Arsenic.

Specimens have also been obtained from the Rishipjerab valley in Hunza and the Shankalpa glacier in Kumaun,‡ but the amount available in either locality is unknown.

Copper-ore, chiefly in the form of the sulphide, chalcopyrite, is common in the schistose beds of the Daling series in Darjeeling district (supra, p. 228) and in Sikkim and in the similar rocks of the Himalayan zone in the Lesser Himalaya of Kumaun.

Copper.

As a rule the lodes are patchy and irregular and no successful attempt has yet been made to exploit them on a large scale. Recently, however, the copper-ores of Sikkim have been attracting considerable attention, but no information is at present available as to the results of prospecting operations.

Iron-ore is known to occur in some quantity in the lower hills in Kumaun,§ where numerous attempts have been made to establish a smelting industry on a commercial basis. All attempts failed however, presumably owing to the cost of transport of ore and fuel and there does not seem to be much prospect of a successful revival of the industry.

Iron.

Iron-ore also occurs in Jammu State, where it underlies the coal measures, but has not been worked except locally and on a small scale.

Numerous other occurrences of iron-ore in the Himalayan region have been recorded, but none of these is at present of economic importance and they need not be enumerated here. Further information, however, will be found in the *Manual of the Geology of India*, part 3 (1881).

Galena, the sulphide of lead, is found at numerous places among the older rocks of the Lesser Himalaya,|| but it is not known to occur in sufficient quantity to warrant serious exploitation.

Lead.

* F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. V, 164 (1886).

† F. R. Mallet: *Memoirs, Geological Survey of India*, Vol. V, 165 (1886).

‡ *Records, Geological Survey of India*, Vol. XXXV, 28 (1907).

§ T. H. Hughes: *Records, Geological Survey of India*, Vol. VII, 15 (1914).

|| V. Ball: *Manual of the Geology of India*, pt. 3, Art. Lead (1881).

APPENDIX.

APPENDIX.

A few addenda and notes of warning which should be read in conjunction with Parts I, II, III and IV.

Peak No. 60, Indus-Nagar Watershed No. 2.

The name "Indus—Nagar Watershed peak No. 2" has been allotted in Great Trigonometrical Survey Synoptical, Volume VII, to two peaks: on page 95-C there is a peak of this name in latitude $36^{\circ} 0' 13''.5$ and longitude $74^{\circ} 55' 1''.5$ of height 24,470. On page 135-C there is a peak of the same name in latitude $35^{\circ} 51' 40''.2$ and longitude $75^{\circ} 0' 20''.7$ and of height 21,390 feet. The origin of this duplication of names has been explained on the ground that the numbering of peaks was started afresh in each square degree, but whatever the explanation, a system under which the same name has come to be applied to two different peaks can in no way be defended. The Indus-Nagar Watershed peaks of pages 92-C and 95-C of Synoptical Volume VII will retain the names hitherto applied to them, whilst the Indus-Nagar Watershed peaks of pages 135-C and 136-C will be called in future Indus-Nagar Watershed peaks No. 7, No. 8, No. 9, and No. 10. Similarly in other cases, in which duplication of names have occurred, alterations will now be introduced.

On page 322 of the *Ice bound Heights of the Mustagh*, Mrs. Bullock Workman and Dr. Hunter Workman give their reasons for thinking that the Survey have miscalculated the position of the Indus-Nagar Watershed peak No. 2, height 24,470 feet. The two explorers ascended to a great height (23,394 feet), and thought at the time that they were climbing a flank of the Survey peak (height 24,470 feet). But when they came to construct their map, they found that the peak which they had ascended was 4 miles north by east of the Survey peak. They were convinced that their peak, which they have named Pyramid Peak, is higher than the Survey peak and they were

"thus placed in the dilemma of considering either that the Survey had miscalculated the position of Peak 2, thus giving it a position four miles too far south, or that Pyramid Peak is another and higher peak not seen and triangulated by the Survey."

The maps of this high region are so inaccurate that they may be disregarded: it is useless to appeal to them. But the positions of peaks were fixed trigonometrically by the Survey, and are probably correct. The position of the Survey peak (24,470 feet) was determined from two independent triangles, and the discrepancy between the two values of position was only 7 feet. The height of this peak was determined from two different places and the two values obtained were 24,482 and 24,461 feet.

The evidence, therefore, is strong that the position of the Survey peak (24,470 feet) has been determined with fair accuracy and cannot be in error by 4 miles.

It is quite possible that a higher peak standing 4 miles behind it escaped observation. The uneven crest-line of the intervening ridge may have obscured the higher peak from one or two of the stations of observation and have left the lower peak visible. The original angle-books show that in 1862-63 Mr. Beverley observed an unnamed peak from his station of Chokh and found it to be 2 degrees east of the Indus-Nagar Watershed peak No. 2. This companion peak was, however, not seen from any other station and Mr. Beverley's observation from one station only could not be utilised.

Peak No. 66, Kuen Lun No. 1.

The height of this peak is uncertain. The position and height of the peak were derived from the observations of Surveyor Ram Singh, Rai Sahib, when he was working under Dr. Stein in 1900; the angle-book was in the handwriting of Dr. Stein himself. Ram Singh is an accurate observer, and his other observations taken at the same time as those of peak No. 66 have proved reliable. We had, however, some initial doubt whether to accept the peak No. 66 or not, because its position had been fixed from one triangle only and that a very acute one. But its height had been observed independently from two different stations, 4 miles apart, and whilst a value of 24,385 feet was obtained from one set of observations, a value of 24,227 feet was obtained from the other set. The agreement between these two values seemed to indicate that a very high peak was standing in this region, and peak No. 66 was admitted into our list on table V. The absence from Dr. Stein's letters and papers of all allusion to this apparently supreme peak of the Kuen Lun made us somewhat uneasy, and when Dr. Stein visited Dehra Dun in December 1908 upon his return from Chinese Turkistan, he was consulted. He expressed his conviction that no peak of 24,000 feet exists in the locality, in which peak No. 66 has been supposed to be standing. Dr. Stein has explored this locality, and could not have failed, he thinks, to have been struck by the appearance of so prominent a peak. He is of opinion that the observations upon which the existence of the peak has been based must be in error.

Tirich Mir.

This description of Tirich Mir is only true if the mountain is viewed from the side of Gilgit or Mastuj. From Chitral the higher flanks of Tirich Mir appear to be precipitous. During the summer it is seldom visible, being either enveloped in cloud or surmounted by a white "flag," which looks like cloud but is possibly fine snow being blown off the summit.

Heights of peaks.

It has been suggested in a review in *Nature*, December 3rd, 1908, page 133, that the altitudes of peaks should be reduced to round numbers, that the height of Mount Everest, for instance, should be given as 29,000 instead of 29,002, and that of Kinchinjunga as 28,150 instead of 28,146. We think, however, that it is best to adhere to the present system, because a precise value of altitude is a ready means to the identification of a peak.

Gasherbrum.

In table XVIII, group XIV, column 6, the bracket should embrace the four Gasherbrum peaks only and not the peak of K².

Kabru.

The name Kabru belongs rather to the high-level ridge itself than to the peak at either end of it.

The height, 21,970 feet, given to the peak at the western end of the Kabru ridge in the third panorama of chart VI is incorrect. The two Kabru peaks are very nearly of the same height, and are both about 24,000 feet: for Tanner's description of Kabru see page 8 of Part I. 21,970 feet is the height of Little Kabru, see Garwood's map attached to Douglas Freshfield's *Round Kangchenjunga*.

Singalila.

Part I, pages 9, 20, 43; Referred to as "Singli" by Rai Bahadur Sarat Chandra Das;
Part II, pages 62, 77, 78, 89; C.I.E.: *Journey to Lhasa and Central Tibet*, page 6.
Part III, page 152.

Karo La.

See Rai Bahadur Sarat Chandra Das, C.I.E.: *Journey to Lhasa and Central Tibet*, page 173.
Part II, page 95.

Yamdruk Tso.

With regard to the name Palti (Yamdruk) see the note by W. W. Rockhill in *Journey to Lhasa and Central Tibet* by Rai Bahadur Sarat Chandra Das, C.I.E., page 188.
Part II, page 95;
Part III, pages 156, 157, 189, 200, 202, 203, 204.

Sangpo.

The word Sangpo should have been written Tsangpo. In the Imperial Gazetteer of India, Volume I, pages 19, 27, Volume IV, page 499, it is written "Tsan-po."
Part II, pages 111, 112;
Part III, pages 125, 127, 128, 157-160, 188.

Kuen Lun range.

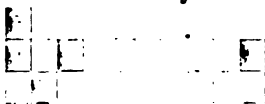
The warning given on page 103 of Part II is repeated here. In the frontispiece of Part I the axis of the Central Kuen Lun has been drawn too far north. In Part II, page 103, footnote. longitude 84° the axis should have been placed in latitude 36°. Chart XXXV repeats this mistake. Chart XXIII is correct.

Huang-Ho.

On this chart Huang should be Hoang.
Part II, Chart XVII.

The Hindu Kush.

It has been pointed out in a review in *Nature*, December 3rd, 1908, page 133, that our description of the Hindu Kush ranges on page 123 of Part III does not tally with figure 2 of chart XXI. The description on page 123 will be found to be in accord with the frontispiece to Part I. As was explained on page 101 of Part II, the figure 2 of chart XXI was purposely made to differ from the frontispiece in order to illustrate our uncertainties. In the two charts we have offered two different solutions of the problem. Whilst we agree with the reviewer in *Nature* as to the difficulties attending orographical analysis, we are of opinion that the uncertainties surrounding the Hindu Kush may prove to be due to the want of systematic surveys and may disappear when more accurate maps become available.

*The Brahmaputra.*

The water-parting between the Brahmaputra and the Tibet Lake basin cannot be drawn with certainty. The position assigned to this water-parting on charts XXIII, XXX and XXXV is conjectural and is not based upon surveys. Until surveys of this region have been carried out, it will not be possible to indicate, except in a very rough way, the northern boundary of the basin of the Brahmaputra.
Part III, page 155.

The warning given in the last paragraph of page 125 of Part III is thus very important. The second paragraph of page 95, Part II, contains the same warning.

APPENDIX.

The Kunar river.

The angle, at which the Sor Laspur tributary joins the Kunar river at Mastuj, is deserving of attention. This tributary is shown on chart XXXIV of Part III, page 155.

Shigatze.

Spelling adopted from the map published with the Imperial Gazetteer. In the body of that work (Volume IV, page 119) it is written Shigatse, a modification of Shi-gatse, the form employed by Major W. F. O'Connor.

The brothers Strachey.

Henry Strachey was alone in 1846; Richard Strachey did not visit Manasarowar till 1848. (Geographical Journal, Volume XV, 1900, and Journal, Royal Geographical Society, Volume XXI, 1851.)

Kurkulti Glacier.

The Kurkulti Glacier flows into the Yasin river, and not into the Hunza as stated on page 196.

Panjal Volcanics.

Since this table was drawn up, the work of Mr. C. S. Middlemiss in Kashmir has tended to show that the Panjal Volcanics are younger than the Lipak series.

GEOGRAPHICAL INDEX.

GEOGRAPHICAL INDEX.

The values of latitude and longitude given in this index to the more important geographical names occurring in Parts I, II, III and IV, are intended only as rough aids to the localisation of places on maps: as many of these values have been derived from small scale maps, the index should not be utilised in scientific discussions or controversies. In certain cases, more especially in those of Tibetan lakes and of passes and glaciers, the values of latitude and longitude rest on doubtful evidence, and have been entered only to enable future explorers to correct our figures. In cases when two or more peaks bear the same name, mean values of latitude and longitude have been given in this index.

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Abrupt peak	35	30	82	30	110, 115 ..	..
Achik Kul	37	3	88	20	199	..
Addan Tso	31	23	87	44	200	..
Afghanistan	..	..	..	..	220, 221, 227, 241, 247, 248, 253, 254, 258, 266.	..
Aghil	36	0	76	40	31, 32, 72, 73, 103, 105, 110, 121.	Frontispiece, xiv
Agram	36	18	71	31	102	..
Aig Kum Kul	37	30	89	15	199	..
Aka Hills	27	0	92	45	216	..
Akhnur	32	54	74	44	168, 180 ..	..
Aksai Chin	35	30	80	30	67	..
Aksu	38	15	74	0	70	..
Alai	39	30	72	0	72, 107 108, 117, 133	Frontispiece
Alaknanda	30	30	79	0	59, 88, 89, 92, 133, 137 to 139, 178, 180, 181, 183 to 185, 188, 190, 195.	x, xi, xiii, xiv, xvi, xxiv, xxxvi.
Alatau	45	0	80	0	107	..
Alichur Pamir	37	45	73	30	70	..
Aling Kangri	32	46	81	2	99, 111, 112, 113, 114, 124, 174, 187.	xx, xxxiv, xxxv
Almaligh	..	..	..	..	133	..
Almora	29	35	79	39	11, 88, 221 ..	..
Altai	46	0	97	0	107	..
Altyn Tagh	37	10	84	0	103, 104 ..	Frontispiece
Ambersilwara, <i>see</i> Imsalwara.	..	..	..	..	..	..
Ammu	27	30	89	0	155	..
Amneh-machin	34	30	99	0	130	..
Amu Darya, <i>see</i> Oxus.	..	..	..	..	..	..
Amuninoku	..	..	..	..	104	..
Anambarula	..	..	..	..	104	..
Angirtakshia	36	0	81	30	109	..
Api	30	0	80	56	6, 12, 13, 18, 33, 142	vii, xiii, xxiv, xxv, xxvi, xxxi.
Api-Nampa	30	0	81	0	13, 77, 141 ..	..
Arakan	21	0	93	0	76, 81, 106 ..	..
Aral	45	0	60	0	68, 105, 108, 119, 198, 201.	..
Arkari	36	0	71	50	123, 186 ..	xx, xxi, xxxiv
Arka Tagh	36	30	88	0	103	..
Arnas	33	12	74	56	168	..
Artush	..	..	..	..	107	..

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Arun Kosi	27	0	87	10	66, 83, 149, 150, 151, 153, 156, 178, 179, 181, 183, 184, 185, 189, 190.	XIII, XV, XXVIII, XXXVI, XXXVII.
Aru Tso	34	0	82	30	205	..
Asnar	..	..	..	..	133	..
Assam	27	30	95	0	218, 228, 265 ..	..
Assam Himalaya ..	28	10	92	0	4, 5, 6, 76, 77, 92, 119, 124, 125, 153, 155, 160, 178, 199, 220.	XV
Astor	35	21	74	52	173, 220 ..	..
Attock	33	53	72	16	171, 172, 174, 177 ..	..
Ayi	31	43	80	0	94	..
Babai	28	45	82	15	144	XXVI
Badraj	30	29	77	57	89	..
Badrinath	30	44	79	17	6, 18, 33, 77, 78, 79, 139, 141.	VII, VIII, X, XI, XIII, XVI, XXIV, XXV, XXXI, XXXIV, XXXV, XXXIII, XXVII, XXVIII
Baghmati	27	10	85	30	132, 144, 148, 181, 189	..
Baghrash Kul ..	42	0	87	0	198	..
Bagini	30	33	79	55	195	..
Baian Kara Ula ..	34	40	96	0	104, 110, 129 ..	..
Baikal	53	0	107	0	198	..
Balasan R.	26	45	88	21	216	..
Balchha	30	48	80	12	92	..
Balkash	46	0	75	0	119, 198, 201 ..	XXIII
Baltistan	36	0	75	0	92, 97, 241, 242 ..	..
Baltoro	35	45	76	30	176, 194, 196 ..	..
Bamian	34	50	67	50	248	..
Bandarpunch	31	0	78	33	6, 18, 39, 139 ..	*VIII, XVI, XXIV, XXXI, XXXIV, XXXV.
Bandipur	34	25	74	40	225	..
Bangahal	32	20	77	0	88, 166, 196, 222 ..	XVIII
Bangalore	13	1	77	35	51	..
Banog	30	29	78	1	9, 89	..
Baralacha	32	45	77	25	84, 166, 167, 168 ..	XIII, XXXI, XXXII, XXXIII, XXXIV.
Baramula	34	13	74	19	168, 169, 180, 224, 225.	XXXIII
Barigar	..	..	..	..	147	..
Barkak	34	22	66	6	102	..
Barmal	34	0	75	50	195	..
Baroghil	36	53	73	21	102, 176, 247 ..	XXXIV
Barphang Gonpa ..	..	..	..	..	145	..
Barpu	36	10	74	50	196	..
Basaoli	32	30	75	49	166	..
Basmagul	34	10	74	10	169	..
Baspa	31	20	78	30	84, 88	XVI, XVIII, XXXI
Bathang	30	0	99	30	.. ..	XXII
Batura	36	35	74	40	196	..
Baxa	26	50	89	36	228	..
Beas	31	45	77	0	84, 88, 90, 132, 161, 165, 178, 180, 181, 188, 211, 245.	Frontispiece, XIV, XVIII, XXIII, XXXI, XXXII, XXXIII, XXXVI.

* The picture of Bandarpunch peak will be found facing page 39 of Part I.

GEOGRAPHICAL INDEX.

275

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Bedasni	30	1	74	28	215	..
Behat	..	..	..	..	168	..
Behling	30	23	78	30	139	..
Beyah	..	..	..	..	165	..
Bhadal	32	22	77	0	166	..
Bhaga	32	40	77	10	166, 167, 196 ..	XXXIII
Bhagirathi	30	30	78	20	59, 78, 89, 133, 137, 138, 139, 178, 181, 185, 188, 190, 195.	X, XI, XIII, XVI, XXIV, XXXVI, XXXVII.
Bhamo	24	15	97	13	126, 127	..
Bharti Khunta	30	48	79	4	19	..
Bhim Tal	29	21	79	33	203	..
Bhoroli	27	15	93	0	.. ..	XXX
Bhotia Kosi	28	0	86	0	83, 84, 149, 151, 180, 181, 185, 189.	XIII, XXVIII, XXXVII
Bhutan	27	0	89	30	216, 220, 221, 228, 241.	..
Biafo	36	0	75	40	96, 176, 194, 196 ..	XXXIV
Bilaspur	31	18	76	47	165, 180	XIX, XXXI
Birehi	29	0	83	0	144, 145, 147, 156, 178, 182.	Frontispiece, XIII, XVI, XXVI, XXXVI, XXXVII.
Birond	29	15	79	43	52	..
Blaini R.	30	55	77	8	223	..
Blue River, <i>see</i> Yangtze.	..	..	..	..	..	..
Boga	31	38	80	4	94	..
Boj	30	54	77	11	224	..
Bolan	29	30	67	30	84	..
Bolor	..	..	..	..	105	..
Bonvalot's peaks	33	30	86	40	110	..
Boorendo	31	23	78	10	84, 164	..
Boyohaghurdonas	36	24	74	42	18	..
Brahmaputra	29	20	90	0	5, 7, 61, 66, 77, 81, 82, 92, 93, 119, 120, 125 to 128, 131, 153, 155 to 160, 171, 174, 178, 179, 182, 188, 189, 190, 216, 220, 256, 263, 266.	Frontispiece, IX, XIV, XV, XVII, XXIII, XXVI, XXVII, XXVIII, XXIX, XXX, XXXI, XXXV, XXXVI, XXXVII.
" , waterparting	..	..	..	..	95, 125, 271	..
north of.	..	..	..	..	..	..
Braldo	35	39	76	0	196	..
Brama	33	30	76	3	196	..
Budi	29	0	80	0	142	..
Bum Tso	31	17	90	57	200	..
Bunji	35	39	74	38	94, 96, 123, 160, 170, 171, 172, 177.	XXXIV
Bunnuk (or Banak)	35	18	75	11	94	..
Buran ghati	31	23	78	10	84	..
Burgi	35	12	75	32	94	..
Buria Gandak	28	0	84	55	83, 146, 147, 148, 185, 189.	XIII, XXVII, XXXVI, XXXVII.
Burkhan Buddha	36	0	97	0	104	..
Burzil	34	56	75	8	84	..
Bus	30	57	78	48	19	..
Byans	30	17	80	50	241	..

GEOGRAPHICAL INDEX.

			LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
			°	'	°	'		
Caroline	..	..	35	20	97	30	114	..
Caucasus	..	..	43	0	43	0	117	..
Chadir Kul	..	..	40	35	75	25	198	..
Chahardar	..	..	35	13	68	45	102	..
Chakmaktin	..	..	37	14	74	20	70, 199	..
Chakrata	..	..	30	46	77	56	222	..
Chamba	..	..	32	33	76	8	88, 166, 170, 220, 223, 224, 225, 242, 243.	XVIII, XXXII
Chambal	..	..	25	40	76	0	139	Frontispiece, IX
Chamlang	..	..	27	47	86	59	4, 18, 37	VI
Chandra	..	..	32	30	77	30	166, 167, 196, 267	XXXIII
Chandra Bhaga	..	..	32	35	77	0	166, 196	XXXIII
Chang	..	..	34	3	77	55	94	..
Changchenmo	..	..	33	2	79	20	.. ..	..
Changlung	..	..	34	15	78	30	242, 243	..
Chaprot	..	..	34	56	77	30	176	..
Charemaru	..	..	36	16	74	19	11, 43	..
Charka	..	..	..	..	..	..	110	..
Charta Sangpo	..	..	29	15	83	17	145	..
Cheena	..	..	29	20	85	10	125, 188, 271	..
Chenab	..	..	29	30	79	30	11	..
.. ..	..	..	33	15	75	0	84, 124, 132, 160, 161, 166, 167, 168, 170, 178, 180, 181, 188.	Frontispiece, IX, XIV, XVI, XVIII, XXIII, XXXI, XXXII, XXXIII, XXXIV, XXXVI.
Cherchen	..	..	38	10	85	30	.. ..	XXII
Chetang	..	..	29	14	91	43	158	..
Chgumbi Dun	..	..	29	45	78	40	85	..
Chiamdo Chu	..	..	30	40	98	0	128	..
Chikkim	..	..	32	21	78	3	237	..
Chilas	..	..	35	26	74	11	241, 242	..
Chingchingmauri	..	..	30	30	81	0	141	..
Chiragh Tar	..	..	37	50	76	0	121, 133	..
Chirhitia	..	..	31	5	79	25	92	..
Chiring	..	..	35	53	76	31	21	..
Chitral	..	..	35	49	71	46	43, 81, 96, 98, 101, 102, 133, 177, 224, 225, 226, 247, 267.	XXI, XXXIV
Chogolisa	..	..	35	37	76	34	17, 22	..
Chogo Lungma	..	..	35	55	75	10	96, 176, 194, 196	..
Chogo Ri	..	..	..	..	..	..	21, 22	..
Chola	..	..	27	28	88	47	13, 14, 18, 62, 77	..
Cholamo	..	..	28	1	88	46	154	..
Chomto Dong	..	..	28	26	88	11	150, 199	..
Cho-ur-dzong	..	..	29	28	85	23	114	..
Chumalhari	..	..	27	50	89	16	6, 13, 14, 18, 33, 44, 84, 92, 93, 125.	XIII, XXVIII, XXIX, XXX, XXXV.
Chumbi	..	..	27	30	89	0	84, 155, 220	XXIX
Chumunko	..	..	27	28	88	47	6, 13, 18	..
Chumurti	..	..	32	0	79	30	91, 241	..
Chur	..	..	30	52	77	29	88, 136, 187, 220, 222.	XVIII, XXIV
Da Chu	..	..	32	0	97	0	128	..

GEOGRAPHICAL INDEX.

277

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Dagshai	30	53	77	6	213, 223 ..	..
Daintar	36	20	74	8	196	..
Dairmal	35	14	74	35	16	..
Dal	34	7	74	51	199, 204 ..	..
Dalhousie	32	32	75	58	166, 223 ..	XXXII
Damodur Kund ..	28	4	85	26	199	..
Dandli	33	32	74	1	266	..
Dangra Yum Tso ..	31	6	86	31	200	..
Dangubash	..	..	..	..	133	..
Daphla Hills ..	27	10	93	40	216	..
Dapsang	35	53	76	31	16, 21, 67, 175 ..	..
Daramdi	..	..	..	..	147	..
Dara Tso	30	57	87	31	200	..
Darel	35	30	75	30	80, 172 ..	..
Darjeeling	27	3	88	16	7, 8, 9, 13, 14, 24, 43, 53, 62, 216, 218, 220, 228, 265, 267. ..	VI, XXII, XXVIII
Darkot	36	44	73	23	102, 176 ..	XX
Dayabhang	28	15	85	31	6, 18, 33, 148 ..	..
Dayamur	35	14	74	35	16	..
Deb Ghat	27	47	84	28	148	..
Deesa	24	15	72	12	51	..
Dehra Dun	30	19	78	3	24, 30, 52 to 54, 85, 117, 136, 163, 179. ..	X, XI, XIX, XXIV
Deo Mir	35	14	74	35	16	..
Deoprayag	30	9	78	36	139	..
Deosai	35	1	75	30	8, 67, 170, 175 ..	..
Deotibba	32	13	77	24	6, 19	..
Devadhunga	27	58	86	20	20	..
Dhansiri	26	0	93	50	.. ..	XXX
Dharma	30	27	80	35	91, 92, 141 ..	XXII, XXV
Dharmasala	32	16	76	20	30	XVIII, XXXII
Dhauladhar	32	0	77	0	72, 79, 87, 88, 165, 166, 188, 192, 242. ..	XIV, XVI, XVIII
Dhaulagiri	28	42	83	30	2, 16, 25, 28, 38, 39, 62, 77, 78, 83, 88, 148, 186, 188. ..	III, IV, V, XII, XIII, XIV, XVI, XXVI, XXVII, XXX, XXXV, XXXVI.
Dhauli	30	45	80	0	92, 133, 138, 139, 183, 195. ..	XXIV
Dhungri	31	5	79	25	92	..
Diamir	35	15	74	30	195	..
Dibang	28	0	95	40	158	XXX
Di Chu	31	0	99	0	127, 129 ..	..
Digi La	29	4	83	32	145, 147 ..	XXVI, XXVII
Digur Thanka	28	40	85	40	93	..
Dihang	28	0	95	30	158, 159, 160 ..	XXX
Dihing	27	25	95	50	.. ..	XXX
Dikhu	26	55	94	30	.. ..	XXX
Dikrang R.	27	8	93	52	216	..
Dingri	23	35	87	20	66, 93, 150, 169 ..	XXVIII
Divanganj	25	10	89	46	153	..
Donkia	27	57	88	51	19, 84	..
Dorah	36	6	71	15	102	..
Drang	31	48	77	1	265	..
Dras	34	26	75	45	91, 170, 173, 174, 175. ..	..

GEOGRAPHICAL INDEX.

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Dre Chu	31	0	99	0	129	..
Dubunni	35	57	74	38	6, 19	..
Dudh Kosi	27	30	86	40	84, 149, 151, 181, 185, 186.	XIII, XXVIII, XXXVII
Dudh Kund	27	44	86	39	199	..
Dugong	30	0	91	45	.. ..	XXX
Dufferin, <i>see</i> Mount.						
Dumche	33	5	79	10	94	..
Dumpho	30	5	88	0	112	..
Dunagiri	30	31	79	52	6, 19	VII, VIII
Dungbura	34	15	92	0	109, 110, 111 ..	..
Dung Chaka	29	57	89	39	21	..
Durung	33	45	76	20	196	..
Duti	30	30	94	15	.. ..	XXX
Elysium Hill	31	6	77	14	223	..
Everest, <i>see</i> Mount.						
Ferozepore	30	56	74	37	55	..
Fishback	28	6	86	41	17	..
Gandak	27	25	84	0	89, 90, 132, 144, 145, 146, 147, 149, 185, 190.	Frontispiece, XII, XXIII, XXVI, XXVII, XXVIII, XXX.
Gandi	..	..	..	..	147	..
Ganditula	..	..	..	..	160	..
Ganges	30	0	78	10	61, 86, 89, 119, 120, 125, 131 to 133, 135 to 141, 144, 180, 188 to 190, 211, 215, 222, 262.	Frontispiece, IX, X, XI, XII, XIII, XXIII, XXIV, XXV, XXXI, XXXV, XXXVI.
Gangotri	30	53	78	52	6, 19, 78, 137, 138, 195	XIII, XXIV, XXXI, XXXIV, XXXV.
Gaoring	27	28	88	47	13	..
Garbiang	30	0	80	0	141	..
Gardhar	32	55	76	43	6, 19	..
Garhwal	30	8	78	48	215, 218, 220, 222, 233, 234, 235.	..
Garjung	32	0	80	15	174	..
Gartang	32	0	80	15	174	..
Gartok	31	40	80	30	164, 174, 180 ..	XXII, XXXIV
Gasherbrum	35	45	76	39	2, 17, 36, 40, 100, 194, 196.	III, XX, XXXIII, XXXIV.
Gau Mukh	30	55	79	10	138, 195	..
Gauri	34	0	76	0	195	..
Gaurisankar	27	58	86	20	6, 19, 20, 33, 149, 151.	VI, XV, XXVIII, XXX, XXXV.
Gaz	38	50	75	20	105, 121	..
Ghaggar	30	40	77	0	136	XXIV
Ghazni	33	0	69	0	.. ..	XXXIV
Giama Nu Chu	30	0	97	15	127	..
Giardong	..	..	..	..	158	..
Gilgit	35	54	74	18	43, 96, 98, 99, 101, 123, 160, 172, 173, 176, 177, 220, 221, 241, 242.	XVII, XX, XXXIV

GEOGRAPHICAL INDEX.

279

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Giri	31	0	78	0	135, 136, 161 ..	X, XI, XXIV
Giumal	32	10	78	14	237	..
Gobi	43	0	100	0	64, 67, 120 ..	..
Godwin-Austen, <i>see</i> Mount.						
Gogra	27	0	81	30	133, 144, 145 ..	..
Gohna	30	30	79	20	177, 203 ..	..
Golabgarh Pass	33	30	75	0	245	..
Gorakhpur	26	45	83	21	25	..
Gori	30	0	80	20	141, 183, 185, 186, 195. ..	XIII, XXV
Goring	30	15	90	15	110	..
Gosainthan	28	21	85	47	2, 17, 38, 39, 62, 83, 147, 149. ..	III, IV, V, XII
Gowra	33	20	76	40	196	..
Great Himalaya	28	0	87	0	5, 26, 31, 61, 71 to 88, 91, 92, 93, 99, 101, 105, 106, 124, 125, 138, 147, 148, 150, 153, 156, 165, 179, 180, 181, 183, 186, 188, 189, 190. ..	Frontispiece, XIV, XV, XVI, XVII, XXXVII.
Great Kara Kul	39	0	73	28	199	..
Gulmarg	34	3	74	24	224, 225	..
Guma	31	58	76	55	265	..
Gum Chu	27	48	86	52	199	..
Gumrang	31	25	78	49	92	..
Gurais	34	37	74	56	170, 244	..
Gurla Mandhata	30	26	81	18	3, 11, 17, 32, 38, 39, 112, 113, 144, 187. ..	IV, V, XVI, XXI, XXIV, XXVI, XXXI.
Gyakharma	30	50	88	30	112, 114	..
Gyala Sindong	29	45	94	15	155, 158, 159, 160 ..	XXX
Hagshu	33	40	76	30	196	..
Hamta	32	16	77	20	84	..
Hangtang	..	..	..	..	150	..
Hanle	32	47	79	0	94	XXXIV
Haramosh	30	50	74	54	4, 18, 41, 96, 183, 187. ..	XXXIV
Haramukh	34	24	74	55	8, 28, 29, 89	..
Hardwar	29	56	78	9	88, 125, 136, 137, 138, 180. ..	..
Hari Rud	34	40	66	0	101, 102, 123	Frontispiece, XXXIII, XXXV.
Harkiang	29	32	85	14	114	..
Harpo	35	24	75	6	94	..
Hasaling	30	0	80	30	183	..
Hatu Pir	35	30	74	30	177	..
Hazara	34	30	73	30	81, 221, 225, 226, 246, 247, 254, 266. ..	..
Helmand	32	0	65	10	102, 119, 120, 122, 201. ..	Frontispiece, XX, XXXIII, XXXIV, XXXV.

	LATITUDE		LONGITUDE		PAGES.	CHARTS.
	°	'	°	'		
Hindu Kush	36	20	72	0	3, 4, 6, 23, 31, 62, 64, 68, 69, 72, 73, 89, 97 to 102, 104 to 106, 119, 122, 123, 177, 186, 187, 189, 196, 198, 220, 247, 248.	Frontispiece, xvii, xx, xxi.
" " , doubtful analysis of the	..	..	..	..	101	..
Hispar	36	5	75	15	96, 194, 196 ..	..
Hoang Ho	36	0	102	0	67, 104, 105, 110, 119, 120, 126, 129, 130, 271.	xvii, xxiii
Hota Sangpo	30	5	88	0	112, 271 ..	..
Humla, <i>see</i> Mount.						
Hundes, <i>see</i> Ngari Khorsum.						
Hunza	36	20	74	40	96, 98, 99, 101, 123, 160, 176, 186, 188, 196, 247, 267.	xx, xxxiv, xxxvi
Hunza-Kunji	36	28	74	36	3, 4, 17, 18, 41, 42, 98.	iv, v, xx
Ibi Gamin	30	55	79	36	17	..
Ikebel—su	38	50	75	15	105	..
Imsalwara	34	25	74	29	243	..
Indrawati	28	0	85	40	151, 181 ..	xxviii, xxxvii
Indus	35	0	73	0	5, 66, 81, 82, 91, 93, 94, 119, 120, 123, 124, 131, 132, 133, 161, 164, 171 to 178, 180, 182, 186, 188, 190, 194, 195, 220, 266.	Frontispiece, ix, xiii, xiv, xvii, xxi, xxiii, xxxi, xxxiii, xxxiv, xxxv, xxxvi, xxxvii.
Indus-Nagar Watershed peak No. 2.	36	0	74	53	269	..
Inylchek	42	15	80	0	194, 197 ..	..
Irak	34	43	68	7	102	..
Irrawaddy	26	0	97	30	119, 120, 126, 127, 128, 157.	xvii, xxiii
Ishpirin	36	42	72	55	101	..
Issik Kul	42	20	77	0	68, 107, 198 ..	Frontispiece
Jadganga					139	..
Jaffirganj	23	54	89	49	153	..
Jahnavi	31	10	79	8	138, 139, 195 ..	xxiv
Jako	31	6	77	15	223	..
Jalalabad	34	26	70	28	247	..
Jalpaiguri	26	31	88	44	54	..
Jammu	32	44	74	52	242, 245, 265, 267.	xxxiii
Jamnotri	31	0	78	33	18	xii
Jang Ninchinthangla	30	22	90	35	110	..
Jano	27	41	88	3	3, 17, 36, 37, 152, 183.	vi
Jaonli	30	51	78	51	6, 19, 78 ..	viii, xxiv, xxxi, xxxiv.
Jaunsar	30	43	77	55	218, 222, 224, 225..	..
Jaxartes	41	0	72	0	119, 120, 121, 122, 201.	Frontispiece, xxiii, xxxv.

GEOGRAPHICAL INDEX.

281

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Jhelum	34	0	74	56	90, 124, 132, 161, 164, 168, 169, 170, 178, 180, 181, 188, 204, 209, 214, 224, 245.	Frontispiece, ix, xxiii, xxxiii, xxxiv, xxxvi.
Jhomogangar	29	50	89	50	21, 113, 114 ..	..
Jiah Bor	27	0	91	42	.. ..	xxx
Jibjibia	28	9	89	50	6, 19 ..	..
Jiparlik	42	0	80	0	197 ..	..
Jomokangkar	..	..	..	..	21 ..	..
Joshimath	30	33	79	34	92, 138 ..	..
Jumna	30	30	78	0	62, 85, 89, 131, 132, 135, 136, 144, 161, 181, 188, 213, 215.	Frontispiece, ix, x, xi, xxiii, xxiv, xxxi, xxxvi.
K²	35	53	76	31	1, 8, 16, 21, 22, 28, 32, 40, 45, 97, 99, 100, 121, 176, 183, 187, 194.	i, ii, iii, xiv, xx, xxxiii, xxxiv, xxxv.
Kabru	27	37	88	7	4, 8, 18, 36, 37 ..	vi
Kabul	34	30	69	11	82, 123, 173, 174, 177, 221, 247.	Frontispiece, xvii, xx, xxxiv.
Kafiristan	35	30	71	0	80, 177 ..	..
Kagbeni	29	0	83	50	147 ..	..
Kailas	31	4	81	19	3, 4, 6, 11, 14, 19, 21, 31, 32, 71, 72, 73, 91, 92, 94, 95, 96, 109, 110, 112, 114, 116, 124, 125, 156, 176, 179, 182, 186 to 189.	Frontispiece, xiv, xv, xxi, xxxi, xxxvii.
Kalabagh	32	58	71	33	172 ..	..
Kalakot	33	13	74	27	265 ..	..
Kalang	26	17	92	0	.. ..	xxx
Kala Tso	28	17	89	18	125, 202, 203, 204, 205.	..
Kali	29	0	80	10	5, 77, 78, 88, 125, 132, 133, 135, 141, 142, 178, 180, 181, 183, 185, 190.	Frontispiece, x, xi, xiii, xvi, xxiii, xxiv, xxv, xxvi, xxxi.
Kaliana	29	31	77	39	51, 52, 53 ..	..
Kali Devi	32	30	76	0	166 ..	..
Kali Gandak	29	0	83	50	83, 146, 147, 148, 155, 156, 159, 181, 182, 185, 186, 188.	xiii, xvi, xxvii, xxxvi, xxxvii.
Kaliganga	30	30	79	15	139 ..	..
Kalka	30	50	76	56	54 ..	..
Kambachen	27	43	88	7	3, 17, 37, 152, 183 ..	..
Kamet	30	55	79	36	3, 11, 17, 32, 38, 39, 45, 77, 91, 92, 94, 95, 101, 112, 113, 187.	iv, v, vii, x, xi, xvi, xxiv, xxxi, xxxiv.
Kami	28	0	93	55	.. ..	xxx

GEOGRAPHICAL INDEX.

		LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
		°	'	°	'		
Kam-pa Dzong	..	28	2	88	30	241 ..	..
Kamri	..	34	49	74	57	84 ..	XIII, XXXIII, XXXIV
Kana, <i>sec Mer.</i>	..						
Kanawar	..	32	0	77	0	197, 220, 234 ..	..
Kangdigar	..	31	20	86	45	114 ..	..
Kangmen	..	30	55	79	36	17 ..	..
Kangra	..	32	5	76	15	222, 243, 265 ..	XIV, XIX, XXXII
Kangrinpoche	..	31	4	81	19	19 ..	..
Kanigang Gonpa	..					145 ..	..
Kankhun	..	36	52	73	3	..	XXXIV
Kansu	..	37	0	103	0	66, 67 ..	..
Kanyara	..	32	12	76	24	265 ..	..
Kaoshan	..	35	16	69	0	102 ..	..
Karak	..	32	10	78	42	..	XXXI
Karakash	..	36	0	78	30	103, 122, 123, 188 ..	Frontispiece, XXXVI
Karakoram	..	36	0	76	0	1, 2, 3, 4, 15, 16, 17, 18, 21, 23, 26, 31, 40 to 42, 62, 66, 71, 73, 96 to 101, 103, 106, 110, 111, 117, 123, 175, 176, 187, 188, 194, 196, 197. 99 ..	Frontispiece, IV, V, XIV, XVII, XX, XXXIV, XXXVI
" pass	..	35	38	77	50	..	..
Kara Kul	..	39	0	73	25	70, 105 ..	..
Kara Nor	..	38	20	97	50	200 ..	..
Karat-chukor	..					133 ..	..
Kargil	..	34	34	76	6	245 ..	..
Karnali	..	28	0	81	12	77, 90, 125, 127, 131, 133, 135, 144, 145, 155, 164, 178, 182, 185. ..	Frontispiece, XII, XIII, XVI, XXI, XXIII, XXV, XXVI, XXVII, XXX, XXXI, XXXVI, XXXVII.
Karnprayag	..	30	16	79	14	138 ..	..
Karo La	..	28	30	90	0	95, 271 ..	..
Kasauli	..	30	54	76	57	89, 213 ..	..
Kashgar	..	39	31	75	56	3, 4, 23, 26, 31, 41, 45, 68, 69, 72, 73, 97, 105, 106, 107, 121, 197. ..	Frontispiece, IV, V, XVII, XXII.
Kashmir	..	34	6	74	51	217, 221, 225, 226, 232, 241, 244, 252, 253, 254, 259, 265. ..	..
Kathgodam	..	29	16	79	36	209 ..	..
Katmandu	..	27	40	85	10	20, 147, 148, 216 ..	XXVII
Kaufmann	..	39	18	72	50	6, 19, 31, 107 ..	..
Kaulia	..	27	49	85	14	7, 20 ..	VI
Kauriala	..					144, 145 ..	..
Kay	..	34	0	77	57	94 ..	..
Kedarnath	..	30	48	79	4	6, 19, 45, 78, 138, 139, 195. ..	VII, VIII, XIII, XXIV, XXXI, XXXIV, XXXV.
Khagan	..	34	48	73	33	170 ..	..
Khalamba	..	30	5	89	50	110 ..	..
Khantongiri	..					150 ..	..
Kharchakund	..	30	47	79	8	6, 19 ..	VII, VIII

GEOGRAPHICAL INDEX.

233

			LATITUDE.		LONGITUDE.		PAGES.		CHARTS
			°	'	°	'			
Khardung	..	..	31	50	79	55	94	..	..
Khatinza	..	..	36	24	71	36	102	..	XXXIV
Khawak	..	..	35	41	69	49	102	..	XXXIV
Khewan Tal	..	..	28	15	83	56	199	..	..
Khingan	..	..	..	..	..	..	81	..	..
Khotan	..	..	37	7	79	59	103, 122	..	..
Khunjerab	..	..	36	45	75	20	99	..	XXXIV
Khunmu	..	..	34	4	75	0	244	..	..
Khurpa Tal	..	..	29	22	79	26	204	..	..
Khyber	..	..	34	1	71	18	84	..	..
Kilik	..	..	37	5	74	43	70, 99, 102, 121, 123	..	XXXIV
Kilong	..	..	31	30	86	25	112	..	..
Kinchiniunga	..	..	27	42	88	9	1, 2, 5, 8, 16, 22, 27, 36, 37, 39, 43, 44, 45, 62, 77, 83, 150, 152, 153, 156, 187, 189, 195.	..	Frontispiece, I, II, III, IV, V, VI, IX, XII, XIII, XV, XXVIII, XXIX, XXX, XXXV.
King Oscar peak	..	..	35	30	87	40	110, 115	..	..
Kingri Bingri	..	..	30	38	80	14	92	..	..
Kioto	..	..	32	26	77	58	236	..	..
Kiria river	..	..	36	0	81	30	103, 122, 188	..	Frontispiece XIV, XXXVI.
Kiris	..	..	35	12	75	54	175	..	..
Kishanganga	..	..	34	35	75	0	82, 88, 169, 170, 178, 181.	..	XXXIII
Kishtwar	..	..	33	19	75	46	142, 160, 167, 168, 170, 180, 265.	..	..
Kisnapur	..	..	25	2	88	28	55	..	..
Kizil-Art	..	..	..	..	..	..	105, 107	..	..
Kizil-su	..	..	39	45	74	0	108, 133	..	..
Koch Korche	..	..	38	20	75	10	197	..	..
Koh-i-Baba	..	..	35	40	67	30	247	..	..
Koikaf	..	..	42	0	80	0	194, 197	..	..
Kojarnath	..	..	30	12	81	14	144	..	..
Koko Nor	..	..	36	53	100	10	67, 104, 126, 130, 198, 200.	..	XXIII
Kokoshili	..	..	35	30	92	0	104, 109, 110	..	..
Koksei	..	..	38	35	75	15	197	..	..
Koktan	..	..	..	..	..	..	107	..	..
Kopang	..	..	31	0	78	40	139	..	..
Koru	..	..	28	8	88	35	84	..	..
Kosa	..	..	30	42	79	45	195	..	..
Kosi..	..	..	26	0	87	12	62, 89, 90, 127, 131, 133, 144, 149, 151, 152, 185, 190.	..	Frontispiece, XII, XXII, XXVII, XXVIII, XXIX, XXX.
Kosila	..	..	29	30	79	10	140, 141	..	XXV
Kotah Dun	..	..	28	25	79	5	85, 141	..	..
Kothri Dun	..	..	29	40	78	40	85	..	..
Koti..	..	..	31	0	75	0	165	..	..
Kotli	..	..	33	31	73	57	266	..	..
Koukye	..	..	..	..	..	..	104	..	..
Krol..	..	..	30	57	76	10	224	..	..
Kuardo	..	..	..	..	..	..	173	..	..

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Kuen Lun	35	48	91	9	4, 18, 31, 32, 41, 66, 67, 72, 97, 100, 103, 104, 105, 107, 109, 110, 122, 126, 129, 186, 188, 197, 199, 230, 270.	Frontispiece, v, xiv, xxxv.
Kuen Lun range, error in drawing the.	..	..	..	..	103	..
Kugart	41	0	74	0	106	Frontispiece
Kulha Kangri	28	4	90	27	4, 18, 37, 39, 44, 77	v, xxix
Kulu	32	0	77	0	31, 84, 165, 195, 222, 242.	..
Kumaun	30	0	80	0	218, 220, 221, 227, 230, 231, 232, 233, 234, 235, 237, 238, 240, 241, 252, 267.	..
Kumaun Himalaya ..	30	30	79	0	3, 4, 5, 6, 32, 74, 76, 78, 79, 83, 92, 116, 135, 178, 187, 195, 199, 203.	xi, xiii
Kumbhkaran Langur ..	..	..	..	..	22	..
Kunlar	34	40	71	0	81, 82, 96, 98, 99, 101, 102, 103, 123, 133, 177, 196, 247, 271.	Frontispiece, xvii, xxxiv.
Kungi	33	40	76	25	196	..
Kungur	38	38	75	16	3, 11, 12, 17, 18, 23, 41, 105.	..
Kunhar	34	40	73	30	170	xxxiii
Kunjut	36	12	75	25	3, 4, 17, 18, 41, 42, 98	v, xx
Kura	29	0	86	32	94	..
Kurkulti	36	30	73	30	196, 272	..
Kurriali	..	..	..	..	133, 144	..
Kurseong	26	53	88	17	24, 52, 53	..
Kyagar Tso	33	6	78	18	199, 205	..
Kyarda Dun	30	30	77	31	85, 136	..
Kyaring Tso	31	8	88	14	112, 200	..
Kyi	29	30	91	0	156, 189, 220 ..	xxx
Lachen-Lachoong ..	27	35	88	42	154	..
La Chen R.	27	50	88	35	221	..
Ladak	34	0	78	0	3, 23, 31, 32, 66, 71, 72, 73, 91 to 95, 101, 106, 111, 112, 113, 116, 125, 147, 150, 156, 164, 171, 179, 180, 181, 187 to 190, 192, 220, 230, 238, 241, 245, 256, 265, 267.	Frontispiece, xiv, xv, xvii, xxi, xxxvii.
Ladda	33	3	75	2	265	..
Laghman	34	35	70	5	247	..
Lahaul	32	40	77	0	31, 84, 88, 192, 242, 267.	..
Landour	30	28	78	6	5, 89	viii, xxiv
Lani La	30	10	92	0	109, 110, 111 ..	..

GEOGRAPHICAL INDEX.

285

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Lankpya	30	28	80	36	92, 141 ..	..
Laowchi	31	50	79	55	94	..
Larji	31	40	77	20	88, 165, 180 ..	XVIII, XXXII
Lasirmou	34	19	77	29	94	..
Leh	34	10	77	34	92, 94, 99, 111, 116, 158, 205.	XXII, XXXIV
Leo Pargial	31	54	78	44	6, 19, 22, 77, 91, 94, 112, 113, 160, 163, 164, 186, 187.	XXIV, XXXI, XXXII, XXXIV.
Lesser Himalaya ..	28	0	83	0	31, 71, 72, 75, 76, 79, 86 to 90, 140, 141, 144, 148, 149, 153, 179, 180, 181, 190, 196.	Frontispiece, XIV, XV, XXXVII.
Lha-ring-po	30	0	94	21	.. ..	XXX
Lhasa	29	41	91	10	109, 111, 125, 155 to 158, 174, 189, 220.	XXII, XXX, XXXVI
Lhobrak	28	0	91	8	154	XXIX
Lhonak	28	0	88	30	241	..
Lidar	34	0	74	50	168, 245	..
Likhu	..	..	..	..	149	..
Lingzi Thang	35	0	79	20	67	XIV
Lio	31	53	78	39	234	..
Lipu Lekh	30	13	81	2	92	..
Lissar	30	20	80	34	91, 141	XXV
Listi Bhansar	28	0	86	30	151	..
Little Kara Kul ..	38	30	75	18	199	..
Lob Nor	39	20	89	10	64, 68, 105, 119, 120, 121, 198, 206.	Frontispiece
Lodhra	33	9	75	8	265	..
Lohari Naig	..	..	..	..	140	..
Lohit	27	50	96	0	158	XXX
Lopra	28	15	90	30	178	..
Lora	29	0	65	0	.. ..	Frontispiece
Lu Chu	..	..	..	..	127, 128	..
Ludhiana	30	55	75	51	54	XIX
Lung	29	30	93	30	.. ..	XXX
Luni	26	0	72	0	.. ..	Frontispiece, IX
Lunkho	36	47	72	26	6, 19, 187	XXI
Ma Chu	35	0	98	0	130	..
Madi	28	0	84	20	181	XIII, XXVII, XXXVII
Mahabarat	27	0	86	0	72, 87, 89, 144, 148, 149.	..
Mahadeo Pokra ..	27	42	85	31	7	VI
Makalu	27	53	87	5	2, 9, 16, 21, 36, 37, 43, 62, 77.	II, III, VI, XXVIII, XXX.
Malla Johar	30	23	80	13	239	..
Malungatti	36	20	75	15	196	..
Mana	30	53	79	37	39, 92, 195	VII
Manas	26	45	91	0	125 132, 153 to 155, 182, 189, 190.	Frontispiece, XXIII, XXIX XXX, XXXVI.
Manasarowar	30	43	81	26	21, 32, 92, 93, 94, 95, 124, 125, 156, 157, 162, 163, 164, 178, 179, 200, 205, 241, 256.	XXI, XXIII, XXVI, XXX, XXXI.

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Mandakini	30	30	79	15	139, 181 ..	XXIV, XXXVII
Mandi	31	43	76	56	180, 265 ..	..
Manghang	30	26	80	44	92 ..	..
Manirang	31	58	78	22	84 ..	XXXIII
Marsemik	34	7	78	35	94 ..	..
Marsyangdi	..	..	..	..	147 ..	..
Maru Wardwan ..	34	0	75	30	160, 168, 195, 196	XXXIII
Masherbrum	35	39	76	16	3, 10, 17, 40, 100, 194.	XIV, XX, XXXIII, XXXIV, XXXV.
Mashobra	31	8	77	17	223 ..	..
Mastuj	36	18	72	40	133, 177 ..	XXXIV
Medosi	32	23	79	27	94 ..	..
Mehowgala	33	13	74	32	265 ..	..
Mekong	32	0	96	0	66, 81, 82, 119, 120, 127, 128, 129.	Frontispiece, XVII, XXIII.
Memonamnyimri ..	30	26	81	18	17 ..	..
Mer	34	1	76	3	6, 14, 19, 36, 79, 175	..
Mhow	22	34	75	46	139 ..	..
Mian Mir	31	32	74	23	55 ..	..
Migi	30	30	91	40	..	XXX
Miju Hills	28	0	96	30	218, 227 ..	..
Milam	30	28	80	11	193, 195 ..	..
Milamchi	..	..	..	..	149 ..	..
Mintaka	37	3	74	55	99 ..	..
Miri Padam	28	21	95	13	159 ..	XXX
Mithan Kot	28	55	70	23	172 ..	..
Mohan	30	11	77	55	85 ..	XIX
Mokieu Tso	30	56	88	57	200 ..	..
Montcalm	34	29	86	52	200 ..	..
Mont Moira	30	52	79	0	19 ..	..
Motretung, <i>see</i> Tso Motretung.	..	..	..	..	..	..
Mount Dufferin ..	38	39	75	13	17 ..	..
Mount Everest ..	27	59	86	56	1, 7, 9, 16, 20, 21, 26, 27, 36, 37, 39, 43, 44, 45, 58, 61, 62, 63, 77, 83, 149, 150, 151, 152, 187.	Frontispiece, I, II, III, IV, V, VI.
Mount Godwin-Austen ..	35	53	76	31	16, 22 ..	..
Mount Humla	..	..	..	..	13 ..	..
Muji	39	0	74	45	121 ..	..
Muktinath	28	33	83	47	147 ..	XXVII
Muling	31	13	79	16	92 ..	..
Muni	33	20	76	35	196 ..	..
Munza Kangri	32	20	87	15	114 ..	..
Murghab	36	0	62	45	..	Frontispiece
Murree	33	55	73	25	214, 242, 245 ..	XXXIII, XXXIV
Murui-ussu	33	45	92	0	104, 129 ..	..
Mushketoff	42	15	80	0	193, 197 ..	..
Mussooreo	30	28	78	5	5, 9, 24, 52, 53, 72, 87, 89, 135, 136, 139, 209, 218, 220, 222, 223.	..
Muth	31	58	78	6	233 ..	..
Muzaffarabad	34	22	73	27	169, 170 ..	XXXIII
Muzaffarnagar	29	28	77	42	51 ..	..
Muztagh	..	..	..	..	97, 99 ..	XX

GEOGRAPHICAL INDEX.

287

		LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
		°	'	°	'		
Muztagh Ata	..	38	17	75	7	4, 11, 12, 18, 23, 41, 45, 97, 121.	V, XXXV
Mywa Guola	..	..	..	..	..	154	..
Nagar	..	36	15	74	45	247	..
Nag Chu Kha	..	31	35	94	0	128	..
Nagong	..	29	15	96	0	.. ..	XXX
Nagsidh	..	30	14	78	6	85	XIX
Nag Tibba	..	30	35	78	9	72, 87, 88, 89, 136, 138, 141, 166, 187.	XVIII
Nahan	..	30	32	77	21	210	..
Nai	..	32	30	76	0	166	..
Naini Tal	..	29	23	79	28	199, 203, 204, 222 ..	VII, X, XI, XXV
Nainpu	..	29	38	93	40	.. ..	XXX
Naktsong	..	30	21	90	1	200	..
Naku	..	28	3	88	30	84	..
Nam Chu	..	30	40	98	0	128	..
Namju	..	..	..	..	..	19	..
Nampa	..	30	1	81	0	6, 12, 13, 19, 77, 78, 91, 125, 144.	X, XI, XVI, XXXV
Nam Tso	..	30	43	90	30	110, 112, 126, 200 ..	..
Nana, <i>see</i> Ser.	..	..	..	..	..	..	..
Nanda Devi	..	30	23	79	58	3, 11, 17, 38, 45, 77, 78, 83, 95, 141, 178, 186, 187, 195.	IV, V, VII, VIII, X, XI, XII, XIII, XIV, XVI, XXIV, XXV, XXXI, XXXV.
Nandakna	..	30	21	79	43	6, 19	..
Nandakot	..	30	17	80	4	6, 19	VII
Nanga Parbat	..	35	14	74	35	2, 3, 10, 16, 17, 28, 29, 32, 38, 39, 42, 43, 45, 79, 80, 83, 160, 186, 187.	* III, IV, V, XIII, XXXIII, XXXIV, XXXV, XXXVI.
Nanshan	..	38	40	96	0	104	..
Napchitai-ulan-muren ..	..	35	15	94	0	129	..
Narayani	..	27	30	84	10	147, 148, 178 ..	..
Nari Khorsam,† <i>see</i> Ngari Khorsum.	..	..	..	..	..	..	..
Narkanda	..	31	17	77	28	62, 78	..
Narsing	..	27	31	88	17	6, 19	VI
Navar	..	30	0	78	40	89	..
Ndu Chu	..	33	45	96	0	129	..
Nela	..	31	10	78	45	196	..
Nepal	..	27	42	85	12	211, 215, 216, 217, 220, 221, 222, 236, 241.	..
Nepal Himalaya	..	28	0	87	0	1, 2, 3, 4, 5, 6, 9, 76, 77, 78, 79, 83, 84, 87, 90, 116, 144, 187, 195, 199.	XIII
Nerbudda	..	22	0	74	0	.. ..	IX
Nezatash	..	37	58	74	1	105	..
Nganzi Tso	..	31	2	87	0	200	..
Ngari Khorsum	..	31	0	80	0	11, 66, 67, 163, 164, 192, 205, 230, 231, 238, 240, 253, 255, 256, 258, 259, 264.	..

* The picture of Nanga Parbat peak will be found facing page 39.

† See page 230 (footnote†).

M

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Nichung	33	17	78	39	.. ..	XXXIV
Nilakanta	30	44	79	24	6, 19	VII
Nilam	28	30	86	30	151	..
Nilang	32	35	77	17	62, 196	..
Nimo Namling	30	26	81	18	17	..
Ninchinthangla	30	20	90	0	31, 72, 81, 82, 95, 99, 109, 110, 111, 114, 156.	Frontispiece, XVII
Ning Kangri	32	15	83	0	114	..
Ningru	30	0	80	56	13, 18	..
Nirpania-ki-Danda	..	..	..	..	142	..
Nissa	36	0	79	20	197	..
Nithal	31	15	78	45	196	..
Niti	30	58	79	53	92, 138, 238	X, XI
Noh	33	37	79	45	112	..
Nojinkang Sang	28	57	90	11	113	..
Nojli	29	53	77	40	30, 52	*
No pass	28	52	84	37	94, 148	XXVII
North Kashmir range	34	20	75	20	72, 87, 88	XIV
Nubra	35	0	77	23	40, 95, 96, 98, 99, 175, 176, 194, 196.	XX, XXXIV, XXXVI
Nu Chu	30	0	97	15	127, 128	..
Nukchung R.	31	8	80	10	258	..
Nuksan	36	22	71	33	102	..
Nun Kun (<i>see</i> Ser and Mer)	34	0	76	4	14, 19, 79, 124, 168, 175, 195, 197, 242.	..
Nushau	36	26	71	50	18	XXX
Nyang	29	0	89	35	92, 93, 95, 125, 156, 189.	..
Ohind	34	0	72	25	171	..
Onchu	..	..	..	..	178	..
Onlet	28	27	95	10	159	XXX
Oprang	36	20	76	0	121, 183, 188	XIV, XXXVI
Oring Nor	34	49	97	49	129, 200	..
Oxus	37	0	68	0	69, 70, 82, 101, 105, 119, 120, 122, 123, 138, 187, 201.	Frontispiece, XVII, XXI, XXIII, XXXIV, XXXV, XXXVI.
Pabar R.	31	0	77	54	224	..
Padam	33	28	76	53	174, 175	XXXIV
Padar	33	25	76	25	265	..
Paghman	34	45	69	0	247	..
Pahlgam	34	2	75	23	245	..
Palgu Tso	28	53	85	33	93, 150, 199	XXVIII
Palti	28	55	90	46	200	XXXVI
Pamir	38	0	74	0	64, 68, 69, 70, 100, 105 to 107, 119, 199, 247, 254.	Frontispiece, XXXV
Panch Chulhi	30	13	80	26	6, 19	VII
Panch Pokri	..	..	..	..	151	..
Pandim	27	35	88	13	6, 19	VI
Pangong	33	57	78	27	95, 111, 126, 188, 192, 200, 202 to 204, 242, 253.	XXXVI

* The picture of Nojli Tower will be found facing page 30.

GEOGRAPHICAL INDEX.

289

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Pangula	28	6	86	35	84, 151, 152 ..	..
Panj	37	10	74	20	123	..
Panjhora	35	12	72	0	.. ..	XXXIV
Panjshir	35	30	69	50	82, 101, 102, 123, 177.	XX, XXI, XXXIV
Passang	30	30	93	30	.. ..	XXX
Pasu	36	30	74	45	196	..
Pathankot	32	17	75	39	54	..
Patli Dun	29	35	78	55	85, 140, 141 ..	..
Pauhunri	27	57	88	51	6, 19, 77 ..	..
Peak, Indus-Nagar Water-shed No. 2.	36	0	74	53	269	..
Peak, Kuen Lun No. 1 ..	35	48	81	9	270	..
Pede	..	..	..	..	200	..
Pemakoi	29	37	94	17	143, 159 ..	..
Phallut	27	13	88	1	9, 20, 26 ..	XV
Phari	27	30	89	0	14, 234, 241 ..	..
Photu	29	24	83	58	94, 147, 155, 188 ..	XXVI, XXVII, XXX, XXXVI.
Phungatori	35	15	74	35	195	..
Piahte	..	..	..	..	200	..
Pindar	30	5	79	30	88, 138, 141, 179, 221	XXIV
Pir Panjal	34	0	74	30	72, 79, 84, 87, 88, 89, 117, 166 to 169, 188, 224, 225, 242, 243.	XIV, XVI, XVIII
Pitak	34	15	77	35	171	..
Po	32	3	78	23	234	..
Potamolam	30	30	91	49	114	..
Po-tung-do	30	0	95	15	.. ..	XXX
Praig Chu	27	31	88	14	262	..
Prool	33	40	76	5	196	..
Prospect Hill	31	5	77	12	224	..
Puga	33	13	78	20	265, 267 ..	..
Punch	33	45	74	5	89	XXXIII
Punjab Himalaya	34	0	76	0	2, 3, 5, 6, 74, 76, 78, 79, 83, 84, 116, 124, 161, 178, 187, 189, 195, 196, 199.	XIII
Quetta	30	12	67	1	.. ..	IX
Raga	29	27	87	0	82, 95, 156 ..	XV, XXX
Raidak	27	0	90	0	62, 85, 125, 132, 153, 154, 155, 182, 190.	Frontispiece, XXIII, XXVIII, XXIX, XXX.
Rajpur	30	24	78	6	52	..
Rakaposhi	36	9	74	29	3, 9, 10, 11, 17, 32, 41, 43, 45, 80, 96, 160, 176, 186, 194, 196.	IV, V, XXXIV, XXXV, XXXVI.
Rakas Tal	30	42	81	13	94, 162, 163, 165, 200	..
Rakiot	35	20	74	37	195	..
Ramganga	29	33	79	0	132, 133, 135, 140, 141, 179, 181.	XXIII, XXIV, XXV
Ranak	..	..	..	..	171	..
Rang	29	8	90	0	156, 157 ..	XXX
Rangit	27	12	88	20	.. ..	XXVIII

GEOGRAPHICAL INDEX.

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Rang Kul	38	35	74	20	70, 199	..
Rapti	28	2	82	0	132, 144, 145, 181 ..	XXIII XXVI, XXVII, XXXVI.
Raskam	36	25	76	30	121	..
Rathong Chu	27	30	88	11	262	..
Rattan Pir	33	35	74	23	72, 87, 89	..
Ravi	32	35	76	0	85, 88, 90, 131, 132, 161, 165, 166, 168, 178, 180, 181, 188, 196, 214.	Frontispiece, IX, XIV, XVIII, XXIII, XXXII, XXXIII, XXXVI.
Remo	35	15	77	25	196	..
Reru	33	8	76	55	196	..
Rich	36	45	73	25	196	..
Rishipjerab	36	41	74	40	267	..
Rohilkhand	29	0	79	0	136	..
Rohtang	32	21	77	14	84, 165	XXXI, XXXII, XXXIII
Rong	29	8	90	0	202	..
Rudok	33	26	79	42	99, 111, 241, 266	..
Rukchu (<i>syn.</i> Rupshu)	33	0	78	0	91	..
Rundun	33	45	76	10	196	..
Rupal	35	10	74	40	124, 194, 195	..
Rupshu	33	0	78	0	203	..
Sabavchy	41	55	80	0	197	..
Sad Ishtagh	36	33	72	7	4, 18, 41, 102, 187, 196.	XX, XXI
Sadiya	27	50	95	40	155, 159	..
Safed Kohs	34	0	70	0	97	..
Saichar Ghainri	35	20	77	10	175, 194, 196	..
Saichu	40	12	94	43	109	..
Saighan	35	10	67	45	248	..
Sairam Nor	44	35	81	10	198	..
Sajum	33	19	79	2	95	..
Sakiz Jarab	36	45	73	40	196	..
Saltoro	35	30	76	50	.. ..	XX
Salt Range	32	40	73	0	232, 246, 253, 254 ..	..
Salween	28	0	98	30	66, 81, 82, 110, 119, 120, 126 to 129, 159.	Frontispiece, XVII, XXIII.
Sama	27	46	93	55	159	..
Samdankang Jang	30	50	91	30	113, 114, 119	..
Samden Khansa	30	48	91	26	114	..
Samye	29	17	91	28	.. ..	..
Sandakphu	27	6	88	0	7, 8, 9, 26, 43, 53 ..	VI
Sangarmarg	33	10	74	40	265	..
Sangpo	29	12	90	0	111, 127, 128, 157, 158, 159, 160, 271.	..
Sanjauli	31	6	77	15	223	..
Sankos R.	26	45	90	0	216	..
Saraswati	30	30	78	0	92, 135	..
Sarda	..	..	..	..	133, 141	..
Sargaroin	31	6	78	30	6, 19	VIII
Sariati	42	15	79	0	121	..
Sarikol	38	0	75	0	12, 31, 68, 69, 72, 73, 105, 106, 122, 133.	Frontispiece, XVII
Sarju	28	23	81	30	88, 133, 141, 144, 145.	XXV, XXVI

GEOGRAPHICAL INDEX.

29

	LATITUDE.		LONGITUDE.		PAGES.		CHARTS.
	°	'	°	'			
Satopanth	30	50	79	20	138, 195	..	VIII
Seistan	31	0	61	50	119	..	..
Semenoff	42	20	80	0	194, 197	..	..
Senchal	26	59	88	18	13, 14, 26, 27	..	..
Ser... ..	33	59	76	2	6, 14, 19, 33, 79, 175.	..	XIII, XXXII, XXXIII, XXXIV.
Sesiri	28	11	95	31	158	..	..
Seti	29	12	81	0	181	..	XXVI, XXXVII
Sha	32	25	76	50	196	..	..
Shafut	38	57	76	5	195	..	..
Shahdulla	36	25	78	4	122	..	..
Shali	31	11	77	20	222	..	..
Shalkar	32	0	78	36	..	..	XXXI
Shalshal	30	49	80	4	92	..	..
Shang	29	32	89	0	156	..	XXX
Shankalpa	30	21	80	23	267	..	..
Sharak Kushta	34	25	66	30	102	..	..
Shar-i	34	48	74	12	170	..	..
Shatul	31	24	77	57	84	..	..
Shawitakh	36	52	73	26	102	..	..
Shemen Tso	34	2	81	39	200	..	..
Sheru	29	2	86	14	94	..	..
Shesha Nag	34	0	73	50	168	..	..
Shigar	35	20	75	40	173, 175, 176, 188, 196.	..	XXIV, XXXVI
Shigatze	29	17	88	54	155, 156, 158, 272	..	..
Shigri	32	17	77	40	167, 267	..	..
Shilla	32	24	78	12	91, 94	..	XXXI, XXXIV
Shimshal	36	27	75	35	99, 188	..	XXIV, XXXVI
Shingo	34	40	75	30	175	..	..
Shipki	31	49	78	48	163, 164, 165	..	XI, XXXI
Sholarung	31	28	78	46	92	..	..
Shorta Sangpo	29	34	85	29	148, 271	..	..
Shudu-Tshenpa	27	57	88	50	..	..	XCIVIII, XXIX, XXX
Shuga	35	50	96	0	104, 129, 130	..	..
Shyal	..	..	..	..	128	..	..
Shyalchikang Jang	31	45	84	45	114	..	..
Shyok	34	48	77	0	40, 82, 94, 95, 96, 98, 99, 123, 124, 171, 173, 174, 175, 188, 196.	..	XX, XXXIV, XXXVI
Siah Koh	34	20	70	0	221	..	..
Sikkim	27	5	88	19	220, 221, 227, 228, 241, 262, 267.	..	..
„ Himalaya	27	40	88	10	60, 153, 195	..	..
Siliguri	26	42	88	25	24, 52, 54	..	..
Silikank	30	53	79	56	92	..	..
Simla	31	6	77	10	53, 88, 131, 214, 218, 220, 222, 223, 224.	..	X, XI, XXIV, XXXI
Simvo	27	41	88	15	6, 9, 19	..	..
Sind	25	45	78	15	171, 262	..	XXXIII
Sindong, see Gyala Sindong.							
Singalila	27	6	88	0	9, 20, 43, 62, 77, 78, 89, 152, 270.	..	..
Singghi	32	27	81	0	95, 173, 174	..	..
Singghi La (Singala)	33	58	76	54	238, 245	..	..

GEOGRAPHICAL INDEX.

		LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
		°	'	°	'		
Sinji Chogyal ..	..	29	37	94	17	159 ..	..
Sir-i-Kul ..	..	37	26	73	46	21, 67, 70, 199 ..	..
Sirkanda ..	..	30	25	78	17	89 ..	..
Sirmur ..	..	30	33	77	42	222 ..	..
Siro ..	..	33	12	74	30	265 ..	..
Sisu ..	..	32	30	77	10	196 ..	..
Siwalik ..	..	29	0	80	0	30, 51, 66, 71 to 76, 85, 86, 135, 136, 140, 141, 153, 154, 165, 179, 188 to 190. 171, 172, 173, 190..	Frontispiece, XIV, XV, XIX, XXXVII.
Skardo ..	..	35	19	75	38	223, 224 ..	XXXIV
Solan ..	..	30	55	77	9	196 ..	..
Sonapani ..	..	32	25	72	20	198 ..	..
Son Kul ..	..	41	50	75	10	84, 91, 92, 124, 160, 164, 178, 181, 197, 219, 225, 226, 231, 232, 233, 234, 237, 252, 266.	XVI, XXXI
Spiti ..	..	32	10	78	0	6, 19, 139 ..	VIII, XXIV, XXXI, XXXIV.
Srikanta ..	..	30	57	78	48	180, 204, 225, 244..	XXXIII
Srinagar ..	..	34	4	74	49	66, 67, 73 ..	..
Ssuchuan ..	..	29	30	104	30	158, 160, 234, 241..	XXX
Subansiri ..	..	28	0	94	15	214 ..	..
Subathu ..	..	30	58	77	2	..	Frontispiece
Suliman ..	..	30	0	69	50	149, 178, 179 ..	XV, XXVIII
Sun Kosi ..	..	27	0	87	0	167 ..	..
Suraj-dul ..	..	32	45	77	26	175, 195, 196 ..	XXXIV
Suru ..	..	34	7	75	58	5, 59, 62, 66, 67, 74, 78, 79, 85, 88 to 90, 92, 94, 124, 125, 127, 131, 133, 135, 144, 155 to 157, 160 to 165, 168, 178, 180, 182, 184 to 186, 188, 189, 196, 197, 220, 259, 264, 266.	Frontispiece, IX, X, XI, XIII, XIV, XVI, XVIII, XIX, XXI, XXIII, XXIV, XXV, XXVI, XXXI, XXXII, XXXIII, XXIV, XXXVI, XXXVII.
Sutlej ..	..	31	43	79	0	82, 177 ..	XVII, XXXIV
Swat ..	..	34	37	72	0	147 ..	..
Sweti-Gandaki ..	..	..	..	..	..	..	..
T ⁴⁵ ..	..	28	6	86	40	2, 9, 16 ..	..
Tagharma ..	..	38	17	75	7	11, 12, 17, 18, 105..	..
Taghdumbash Pamir ..	..	37	12	75	0	70, 105, 133 ..	..
Takachull ..	..	30	13	80	26	141 ..	..
Takla Kar ..	..	30	17	81	7	144 ..	..
Takla Makan ..	..	39	0	80	0	122 ..	..
Taku ..	..	29	3	85	8	94 ..	..
Tal R. ..	..	30	0	78	19	215 ..	..
Talung ..	..	27	32	88	30	..	XXVIII
Tamba Kosi ..	..	27	30	86	0	149, 150 ..	XXVIII
Tambar ..	..	27	0	87	30	84, 150, 152, 181, 195	XIII, XXVIII, XXXVII
Tambur ..	..	..	..	..	..	150, 151 ..	..
Tamor ..	..	..	..	..	..	149, 150, 152 ..	..
Tamru ..	..	..	..	..	..	150, 152 ..	..
Tandi ..	..	32	35	76	50	166, 167, 180 ..	..

GEOGRAPHICAL INDEX.

292

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Tang	27	50	89	10	84	..
Tangitar	..	..	..	..	107	..
Tangla	33	0	92	0	109, 110, 111, 129..	..
Targot	30	40	86	15	112, 128 ..	..
Targot Yap	30	40	86	15	113, 114 ..	..
Tarim	40	0	80	30	47, 64, 67, 70, 97, 102, 103, 105, 108, 119 to 123, 126, 198, 201, 206. 194, 195 ..	Frontispiece, XIV, XXII, XXIII, XXXIV, XXXV.
Tashing	35	13	74	46	70, 105, 121, 123, 133, 138.	..
Tashkurgan	37	45	75	22	..	..
Tawi	33	0	75	15	..	XXXIII
Tenga	27	49	95	49	158	..
Tengri Khan	42	24	80	17	6, 14, 19, 31, 107, 121	..
Tengri Nor	30	40	90	30	109, 110, 126, 128, 200. 107	..
Terek	..	..	..	..	175	..
Tertse	..	..	..	..	84, 151	..
Thanglang	28	28	86	21	94, 171, 190 ..	..
Thangra	33	10	78	45	6, 19	..
Tharlasagar	30	52	79	0	266	..
Thok Jalung	32	28	81	37	6, 14, 31, 64, 68, 69, 72, 73, 105 to 107, 116, 117, 119 to 122, 193, 194, 197, 198, 247.	Frontispiece, V, XVII, XXIXV.
Tian Shan	42	20	80	0	271	..
Tibet Lake basin	33	0	84	0	145	..
Tibrikot	28	36	82	44	139	..
Tihri	30	23	78	30	..	..
Tila	29	13	82	0	..	XXVI
Tilail	34	34	75	3	170, 244 ..	..
Tipta	27	50	87	40	83	..
Tirich Mir	36	22	71	51	3, 4, 11, 17, 18, 32, 36, 41, 42, 43, 69, 98, 101, 102, 122, 123, 186, 196. 133	IV, V, XX, XXI, XXXIV, XXXV, XXXVI
Tisnaf	..	..	..	..	5, 62, 77, 82, 84, 85, 89, 90, 132, 153, 154, 181, 185, 195, 221, 228, 262.	Frontispiece, XII, XIII, XXIII, XXVIII, XXIX, XXX, XXXVI.
Tista	27	0	88	28	14, 52	..
Tonglu	27	2	88	5	..	XV
Tongul	34	4	75	56	..	XXXIV
Tons	31	0	77	52	89, 135, 181, 224 ..	X, XI, XXIV, XXXVII
Tossun Nor	35	18	98	41	200	..
Tradom	29	39	84	11	155, 157 ..	..
Tragbal	34	35	74	40	225	..
Trans Alai	39	0	72	0	6, 31, 68, 72, 107, 108	Frontispiece
Tribeni	27	28	83	57	147	..
Trisul	30	17	79	50	6, 19, 147 ..	VII, XXIV, XXXI
Trisuli Gandak	28	0	85	20	83, 146, 148, 185, 188	XIII, XXVII, XXXVI
Tsailam	37	0	92	0	66, 67, 104, 1. 6, 129, 201.	Frontispiece, XXIII
Tsang	28	30	90	30	192, 205 ..	..

	LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
	°	'	°	'		
Tsangpo, <i>see</i> Sangpo.						
Tsaring Nor ..	34	53	97	6	129, 200	..
Tsati ..	34	32	77	43	176	..
Tso Kar ..	33	18	78	0	199	..
Tso Kyagar, <i>see</i> Kyagar Tso.						
Tso Mereri ..	32	53	78	20	199, 202, 203, 204..	..
Tso Motretung ..	28	26	88	11	150, 199, 205	XXVIII
Tso Phomo Chang ..	28	36	90	20	199	..
Tso Rombudsa ..	28	48	90	51	199	..
Tso Tigu ..	28	40	91	46	199	..
Tuan ..	33	3	76	35	196	..
Tuna ..	27	58	89	16	241	..
Tungchen ..	28	55	90	50	200	..
Turkistan, Russian ..					248	..
Turtuk ..	34	50	76	48	175	..
Ullug Mustagh ..	36	30	87	20	115	..
Ulu-Art ..	39	0	74	45	105, 121	..
Unmaru ..	34	43	77	16	175	..
Untadhura ..	30	34	80	14	92	..
Uri ..	34	5	74	0	169, 224, 225	..
Uzbek ..	38	40	73	50	105	..
Victoria Lake ..	37	26	73	46	21, 199	..
Vihi ..	34	4	75	0	225, 244	..
Vindhya ..	28	0	78	0	47, 136	..
Virnag ..	33	32	75	14	168	..
Vishnuganga ..	30	40	79	37	77, 92, 138, 195	XXIV
Wakhan ..	37	0	73	0	70, 247..	..
Wardwan, <i>see</i> Maru Wardwan.						
Wasmu ..	36	25	73	0	196	..
Wular ..	34	21	74	35	165, 168, 169, 170, 199.	XXXIII
Wulas ..	32	19	76	50	166	..
Yala ..	29	10	91	50		XXX
Yala Shimbo ..	28	48	91	59	113	..
Yalung ..	27	40	88	0	152, 195	..
Yambulak ..	38	17	75	5	197	..
Yamdruk Tso ..	28	55	90	46	95, 156, 157, 189, 200, 202, 203, 204, 271.	XXX, XXXVI
Yangla Dhar ..					142	..
Yang-sang ..	29	10	95	0		XXX
Yangtze ..	33	40	96	0	66, 67, 81, 82, 105, 110, 119, 120, 126 to 129.	Frontispiece, XVII, XXIII.
Yanymya ..	39	0	74	45	121	..
Yarkand ..	38	25	77	13	66, 70, 73, 103, 121, 122, 183, 188, 247.	Frontispiece, XIV, XXXVI.
Yarkhun ..	36	33	72	55	101	XX, XXI
Yaru ..	28	14	88	0	150	XXVIII
Yasin ..	36	22	73	10	133	XXXIV
Yeshil Kul ..	37	45	73	2	70, 199	..
Yurangkash ..	37	0	80	0	122, 186, 188	XXXVI

GEOGRAPHICAL INDEX.

295

			LATITUDE.		LONGITUDE.		PAGES.	CHARTS.
			°	'	°	'		
Zarafshan	..	..	36	0	78	0	97, 121 ..	..
Zaskar*	..	..	34	0	77	20	3, 6, 31, 32, 72, 77, 79, 91, 92, 94, 101, 113, 116, 125, 141, 171, 173 to 175, 178, 181, 186 to 188, 196, 230, 236, 242, 245, 246.	Frontispiece, XIV, XVI, XVII, XXI, XXXIV, XXXVI.
Zayul	..	..	28	0	97	5	82, 159 ..	XVII, XXX
Zemu	..	..	27	45	88	20	195 ..	..
Zilling Tso	..	..	31	45	88	57	200 ..	..
Zingzingbar	..	..	32	35	77	25	167 ..	..
Zoji	..	..	34	17	89	10	79, 84, 88, 170, 175, 188.	XIII, XXXIII, XXXIV XXXVI.
Zungaria	..	..	45	0	85	0	107	..

* See page 230 (footnote †).

INDEX OF SUBJECTS.

	PAGE.
Africa, N., extension of Tethys to	254
Africa, S., tillites of	226, 228, 251
A—K, <i>see</i> Kishen Singh.	
Albrecht, Professor	50
Alexander the Great	102
Alluvium, Indo-Gangetic, age of the	76
„ , Kashmir	169
„ , Nepal	148
„ , Ngari Khorsum	163
Altitude, apparent variations of, due to snow	24, 32
„ , as a means of identifying peaks	16
„ , errors in determination of	23
America, geological affinities of Himalaya with	250
Andesite	238
Angaraland	254
Antecedent rivers	263
Antimony	267
Archæan group	221, 227, 246, 247
Arsenic	267
Aryan group	232, 237, 241, 242
„ period	251
Attock slates	247
Attraction of Himalaya	24, 51
Austen, <i>see</i> Godwin-Austen.	
Australia, affinity between India and	228
„ , supposed Cambrian tillite in	228
„ , Talchir tillite in	226, 251
Avalanches, mud	65
Baluchistan, extension of Tethys to	254
„ , gorges of	263
Barckley, W. C. G.	17
Barren Island	256
Barus beds	245
Bawar quartzite	224
Baxa series	218, 222, 228, 229
Beryl	219
Bifurcation of ranges	76, 77, 85, 88, 91, 95, 100, 104
„ , effect of, on Himalayan rivers	178
Biotite-gneiss, graphitic	221
Blackwelder, E.	253
Blaini series	223, 224, 225, 226, 228, 249
Blanford, H. F.	153
Bogle, George	157
Boileauganj series	224

	PAGE.
Bokhara, extension of Tethys to	254
Borax	265
Boulder-slate	222, 223, 224, 225, 226, 228
Bower, Captain H.	109, 205
Bullock Workman, <i>see</i> Workman.	
Burma, Siwalik series in	210
Burrard, Col. S. G.	263
Calcareous sandstone stage	234, 239
Cambrian epoch in Himalaya	227, 250
" system	233
Campbell, Dr. A.	14, 18
Cape, Gondwanas at the	228
Capture by rivers	202, 262
Carbonaceous system	222, 223
Carboniferous period, disturbances during	252
" system	233, 243, 245
Carter, H. J.	19
Central gneiss	219
Chalcopyrite	267
Chikkim series	237, 243
China, geological affinities of Himalaya with	228, 249, 250
" , mountains of, as related to Tibet	67
" , tillite in	228, 249
Coal	214, 215, 216, 265, 266
" , shale mistaken for, at Simla	223
Colebrooke, H. T.	137, 138
Collie, <i>see</i> Norman Collie.	
Companion peaks	36
Conglomerate, Siwalik	210
Conway, Sir Martin	8, 21, 22, 65, 100, 172, 176, 193
Conyngham, <i>see</i> Lenox Conyngham.	
Copper	228, 267
Coral limestone	239
Crawford, Colonel Charles	18, 148, 149
Cretaceous system	238, 241, 246, 248
" , resemblance between Indian and African	228
Crystalline rocks, peaks composed of	44
" schists	218, 220
" zone in Hazara	247
Cuddapah system	227, 229
Cunningham, Sir Alexander	87, 91, 92, 116, 117, 165, 166, 171, 173, 175
Curzon, Lord	12, 20, 69, 70
Dagshai stage	209, 213, 214
Daling series	218, 222, 227, 228, 229
" " , copper-ore in	267
Dalrymple, Alexander	157
Damuda series	216, 229
D'Anville	157, 200
Daonella beds	239

SUBJECT INDEX.

299

	PAGE.
Das, Rai Bahadur Sarat Chandra, C.I.E.	230, 270, 271
Deasy, Captain H. H. P.	66, 115, 117, 204, 205
Deccan trap period in Himalaya	256
Denudation in Gilgit	176
Deoban limestone	218, 222, 224
Desiccation	204
Devonian system	233, 243, 247
Dharwar system	226, 227, 228
Disturbance, tectonic, in Himalaya	258, 260
Dothak series	234
Drainage lines, antiquity of	259
„ system, pre-pliocene	259
„ „ , reversal of Himalayan	259
Dravidian group	232, 237, 240, 247
Drew, Frederic	92, 116, 117, 167 to 169, 192, 202 to 204, 241
Duns	66, 85, 103, 107, 151, 258
Dutreuil de Rhins, J. L.	128
Dutton, Major C. E.	48, 49, 213
Du Vernet, Captain J. S.	19
Earthquakes	46, 260
Economic geology	265
Elevation, errors in measurement of angles of	25
„ , recent	46, 65, 178, 260, 261
Elias, <i>see</i> Ney Elias.	
Eocene	215, 238, 246
„ period, conditions in Himalaya during	256
Erosion, effects of, in the Siwalik range	86
Everest, Sir George	20, 51
Exotic blocks of Malla Johar	238
Fault, main boundary	211, 215
Fedchenko, A.	68
Fenestella shales	233, 244
Ferber, Aug. C. F.	99
Fermor, L. L.	221
Fisher, Rev. O.	48, 49, 213
Floods	177
Flysch	238, 239
Folds, reversed	211, 229
Forsyth, T. D.	107
Fraser, David	94, 117
Fraser, J. B.	79
Freshfield, D. W.	44, 153, 195
Gabet, Father	128
Galena	267
Gangamopteris beds of Kashmir	244
Garwood, Prof. E. J.	44, 262, 264
Gerard, Captain A.	18, 79, 84, 164
Gilbert, G. K.	48

	PAGE.
Gill, Captain W. J.	116
Giumal series	237, 246
Glacial epoch, Aryan	251
" " , Gondwana	252
" " , pre-Talchir	228
Glaciers	9, 78, 88, 96, 105, 124, 152, 192
<i>Glossopteris</i> in Himalaya	216
G. M. N., <i>see</i> Nem Singh.	
Gneiss	221, 227, 247
" , peaks composed of	44
Gneissose granite, <i>see</i> Granite.	
Godwin-Austen, Col. H.	8, 65, 86, 91, 92, 173, 192, 216, 231, 241
Gold	266
Gondwanaland	251, 255, 257, 258
Gondwana system	215, 216, 217, 228, 244, 252
Gordon, Robert	126, 127, 128, 157
Gore, Colonel St. G. C.	5
Gorge, Alaknanda	137
" , Arun	149, 150
" , Beas	165
" , Bhagirathi	137, 139
" , Bhotia Kosi	151
" , Chenab	167
" , Gandak	146, 147
" , Indus	171, 172
" , Jhelum	169
" , Jumna	135, 136
" , Karnali	144
" , Ravi	166
" , Shyok R.	175
" , Suru R.	175
" , Sutlej	78, 165
Gorges, absence of, from N. Kashmir range	89
" , alternation of	190
" , origin of Himalayan	184, 262, 263
" , proximity of high peaks to	185
" , relation of, to lakes	189
Gothlandian in Himalaya	233
Graham, W. W.	8
Granite	44, 218, 219, 220, 242, 247
" , gneissose	219, 247
" , Tertiary	256
Granulite, pyroxene	221
Gravity, deviation of, from normal	24
Great Limestone	243
" Grey limestone "	236
Grey shale stage	239
Griesbach, C. L.	45, 141, 231, 232, 238, 258
Gypsum	248, 266
Haimanta period, conditions during	250

SUBJECT INDEX.

301

	PAGE.
Haimanta system	220, 232
Halobia beds	239
Hamilton, Buchanan	149
Hanging valleys	262
Harcourt, Captain A. F. P.	165, 167
Harmar, Captain H. J.	7, 158, 159
Hayden, H. H.	202, 204
Hayward, G. W.	68, 105, 117
Hedenstræmia beds	239
Hedin, <i>see</i> Sven Hedin.	
Hennessey, J. B. N.	109, 127, 129, 159
Henry of Orleans, Prince	127, 128
Herbert, Captain J. D.	17, 19, 79, 88, 138, 139
Himalaya, age of the	76, 258
" , application of name	75, 76
" , attraction of	51
" , cross-sections through the	76
" , history of	249
" , ranges of	75
" , rise of the	29
Himalayan rivers	131
" " , age of	210
" " , convergence of	190
" " , development of	139
" " , direction of flow of	178
" " , discharge of	132
" " , nomenclature of	133
" " , orders of magnitude of	131
" " , positions of sources of	181
" " , sections of	131
" " , source of supply of	145
" " , zone	218
Hindu Kush, doubtful analysis of the	101
Hodgson, Brian	20, 60, 61, 62, 87, 147, 148, 149, 150
Hodgson, Captain J. A.	17, 19, 88, 137, 138, 140
Holdich, Sir Thomas	17, 64, 66, 99, 100, 102, 103, 109, 119, 122, 155, 177
Holland, Sir Thomas	193, 203, 226, 231, 250, 251
Hooker, Sir Joseph	15, 19, 60, 62, 116, 117, 150, 154, 183, 192
Huc, Father	128
Humboldt, A von	68, 100, 105
Hunter Workman, <i>see</i> Workman.	
Huntington, Ellsworth	68, 107, 192, 203, 204, 205, 206
Indo-Tibetan water-parting	125
Indus valley Tertiaries	245
Infra-Krol series	224
Infra-Trias of Hazara	225, 247
Iron	214, 267
" Isle Tibet "	253
Isostasy	43, 186, 213

	PAGE.
Jaunsar system	218, 222
"Jilga"	107
Jurassic period, changes during	254
" system	216, 236, 237, 241, 246, 248
Juvavites beds	239
Kampa system	241
Kanawar system	233, 234, 240
Karewa	169, 259, 264
Karoo system	228
Kasauli stage	209, 213, 214
Kinthup	159
Kioto limestone	236
Kirkpatrick, Colonel	148
Kishen Singh, Pandit	21, 109, 110, 111, 113, 114, 127, 129, 157, 159, 193
Klaproth	157
Klippen	240
K-P, <i>see</i> Kinthup.	
Krol limestone	224
Kropotkin, Prince	173
Kuen Lun range, error in drawing the	103
Kuling shales	243
" system	234, 243
Kyanite schist	220
Lagoons, Tertiary	214
Lake basin of Central Tibet	198
" terraces	164
Lakes	198
" , desiccation of	204
" , gorges due to	263
" , intermittent outflow from	150
" , Mongolian	126
" , obliteration of, by sand	206
" , old, in Indus valley	173
" , origin of, in Kumaun	202
" " in Tibet	202
" , outlets of Tibetan	205
" , Tibetan	126
Lala	159
Laterite, Tertiary	214
LaTouche, T. D.	216
Lead	267
Lenox Conyngham, Major	53
Lignite	210, 266
Lilang system	235, 243
Limestone, crystalline	221
Lipak series	234
Littledale Mrs.	110
" St. G. R.	109, 110, 111, 204, 256
Lloyd, Sir W.	164

SUBJECT INDEX.

303

	PAGE.
Longe, Colonel F. B.	57
Longstaff, Dr. T. G.	11
Lydekker, R.	45, 80, 170, 172, 204, 231, 241, 242, 243, 259
Maclagan, General R.	166, 172
Main boundary fault	211, 215
Mallet, F. R.	216
Malmesbury series	228
Mandhali series	224
Manning, Thomas	157
Map-drawing, principles of	57
Markham, Sir Clements R.	61, 148
Massive limestone series	222
McMahon, Lt.-Genl. C. A.	44, 192, 219, 220, 222
" , Sir Henry	81
Medlicott, H. B.	212, 214, 215, 217, 222, 223, 224, 263
Meekoceras zone	239
Megalodon limestone	236
Meridional ridges	60
Merzbacher, Dr. G.	14, 68, 107, 193
Mica schist	220
Middlemiss, C. S.	48, 49, 50, 81, 85, 141, 204, 211, 212, 215, 225, 247, 258
Miocene, Lower	214
Monotis shales	239
Montgomerie, Colonel T. G.	8, 11, 15, 16, 18, 21, 25, 28, 29, 100, 110, 111, 116, 150, 151, 157, 169, 170, 174, 177
Moorcroft, W.	97, 138
Moraines, Arun valley	150
Mountain compensation, Pratt's hypothesis of	52
Mountain ranges	47
" " , origin of	48
Mud avalanches in Himalaya	65
Mullah	172
Munshi	100
Murchison, Sir Roderick	123
Murree beds	214, 246
Muschelkalk	236
Muth system	233
Nahan stage	209, 210
Nain Singh, Pandit	73, 99, 109 to 114, 157, 158, 174
Nem Singh	158, 159
Neutral Zone	213
Neve, Dr. A.	175
Ney Elias	17
Nodular limestone	239
Norman Collie, Professor	17, 22
Norpu	159
Nummulitic limestone	214, 238, 246

	PAGE.
Oestreich, Dr. Karl	20
Oldham, R. D.	169, 170, 184, 185, 192, 202 to 205, 212, 213, 222, 262, 263, 264
Ophiceras zone	239
Ordovician system, Himalayan representative of	233
Orpiment	267
Ossiferous beds of Ngari Khorsum	259, 261, 264
Otoceras zone	235, 243
Panjal system	224, 241, 242, 243, 244
Para limestone	236
Peaks, above 24,000 ft.	1
" , alternative names of	16
" , analytical table of	37
" , below 24,000 ft.	6
" , classification of, according to altitude	33, 34
" , companion	36
" , frequency of occurrence of, of certain altitudes	31
" , geographical distribution of	36
" , geology of Himalayan	44
" , identified by height	16, 270
" , Karakoram system of	40
" , method of fixing position of	13
" , names of	15
" , origin of	45
" , position of highest, with regard to ranges	61
" , principal	36
" , satellite	36
" , effects of snow on	32
" , subdivision of, in Himalaya	33
" , summary of Himalayan	39
" , Tibetan	113, 114, 115
" , twin	36, 39
Pemberton, Captain B.	154
Pendulum observations	53
Permian system	235
Permo-Carboniferous beds in Assam	234, 241
Persia, recent volcanoes in	256
Petermann, Dr. A.	204
Pilgrim, G. E.	216
Plateaux of Asia, nature and origin of	65
Pleistocene deposits	259
Pliocene crustal movement	258
Plumb-line, deflection of	24, 51
Po series	233, 234
Pratt, Archdeacon	52
Prejevalsky, N.	66, 67, 73, 103, 104, 110, 129, 130
Productus Limestone in Afghanistan	248
" shales	235, 243, 244
Punjab, Siwalik series in	210
Purana group	227

SUBJECT INDEX.

305.

	PAGE.
Purana group, tillite in	228.
" sea	249, 256
Purdon, W. H.	169
Purple Slate series	218, 222
Pyroxene-granulite	221
 Quartzite series	 239
 Rainfall, recent diminution of	 126
Rajputana, extinct river of	136
Ram Singh, Rai Sahib	17, 18 115, 121, 270.
Ranges, bifurcation of	76, 77, 85, 186
" , classification of	71, 271
" , continuity of	73.
" , divergence of	73.
" , mutual obliquity of, in Punjab	90
" , parallelism of, Nepal	90
" , probable continuity of, in Central Tibet	109
" , sympathetic maxima and minima of	187
Raper, Captain F. V.	137
Rawling, Captain C. G.	162, 204, 206.
Red quartzite stage	233
Refraction, atmospheric	25.
Rejuvenation of rivers	261
Rennel, J.	136, 137, 157
Rewa, tillite in	228.
Richthofen, Baron von	65
Ridges, as distinct from ranges	71
" , meridional	60.
" , transverse to Zaskar range	92
Rinzin	13, 142
Riverbeds, gradients of	178, 180.
" deposits	173
" development	179
" " , Himalayan	139.
" gradients, variations in	182
" system, Himalayan, origin of	47
" valleys, conjunction of, behind Mussooree ranges	89
Rivers	119
" , antecedent	263
" , convergence of	144, 155, 190.
" , erosive effects of	66
" , erosive power of	161
" , Himalayan, <i>see</i> Himalayan rivers.	
" , intersection of ranges by	77
" , order of magnitude of	120.
" , rejuvenation of	261
" , Siwalik	210
" , troughs of Burmese and Eastern Tibetan	82
Robert, W.	17, 149.
Rockhill, W.W.	114

	PAGE.
Rock-salt	248, 265
Ruskin, John	10, 58
Ryall, E. C.	11, 14, 19
Ryder, Major C. H. D.	7, 17, 18, 93, 94, 95, 110, 111, 113, 114, 125, 156, 162, 163, 200
Saligram	250
Salinity as evidence of desiccation	205
Salt	248, 265
Salt-Range, boulder-bed of	225
Salt-wastes of Tsaidam	67
Sand, lagoons choked by	121
Sand-rock, Siwalik	210
Sapphire	265
Sargent, R. H.	253
Satellite peaks	36
Schlagintweit, Adolphe de	173
Schlagintweit, Hermann de	9, 16, 17, 20, 21, 79
Seistan, lagoon of	119
Semenoff, M. P. P.	97, 107, 117
Severtsoff, N.	68, 106
Shaw, R. B.	123
Sherring, Charles A.	11
Sherwill, Captain W. S.	9
Shillong plateau, during Cretaceous period	255
Simla slates	218, 222, 223, 247
Sind, Siwalik series in	210
Sirmur series	209, 213, 214, 215
„ „ , coal in	214
Siwalik series	209, 248
„ „ , lignite in	210, 266
„ „ , relation of, to Sirmur series	215
Slate	265
Slate series of Hazara	247
Snow, apparent variations of altitude due to	24
Snow, line of perpetual	32, 116, 117
Spencer, H.	145
Sphene	220
Spinel	221
Spiti shales	237, 238, 241, 246, 254
Stein, Dr. M. A.	62, 97, 197, 270
Stevenson, David	58
Stibnite	267
Stoliczka, F.	69, 105, 107, 231, 233, 241, 247
Strachey, Henry	11, 65, 67, 144, 162, 163, 174, 175, 272
„ , John	144
„ , Sir Richard	11, 17, 32, 71, 79, 116, 117, 139, 144, 162, 230, 264, 272
Strahan, Colonel George	39, 139
Sub-Himalayan zone	209
Subathu stage	209, 214

SUBJECT INDEX.

307

	PAGE.
Subsidence, Cretaceous	254
Suess, Prof. E.	47, 69
Sulphur	267
"Supra-Kuling" series	243
Sven Hedin, Dr.	12, 64, 66, 67, 69, 73, 97, 103, 105, 109, 110, 115, 121, 122
Tagling limestone	236
Tal series	215
Talchir boulder-bed	225, 226, 231
Tanner, Colonel H. C. B.	7 to 10, 13, 15 to 18, 33, 37, 42, 80, 138, 141, 142, 144, 146, 149, 154, 159, 172
Tarus, glacial	203
Tertiary system	238, 241, 245, 246, 248
Tethys	47, 227, 237, 245, 248, 251, 252, 253, 254, 255, 260
Thuillier, Sir Henry	58
Tibetan zone	230, 241, 244, 248
Tillite	222, 223, 224, 225, 226, 251
" , in China	249
" , pre-Gondwana, in Peninsula	227, 228
Transgression, Cretaceous	254, 255
Trap, Panjal	245
Trias	235, 246, 248
" , Himalayan representatives of Alpine	237
Tropites beds	239
Trotter, Colonel H.	11, 12, 17, 112, 128
Troughs, Himalayan, heights of floors of	179
Turner, Capt. S.	157
Twin peaks	36, 39
Unconformity, Palæozoic	234, 244
Vaikrita system	218, 220, 221, 232, 247
Valleys, alluvial	87
Verchere, A. M.	231, 241
Vertebraria in Himalaya	216
Vindhyan system	227
Volcanic period, Carbonaceous	250
" " , Cretaceous	256
" " , Jaunsar	249
" " , Panjal	252
Volcanic periods, Dravidian	250
" " , Purana	249, 250
Volcanic rocks, basic, of Malla Johar	238
" " , in Carbonaceous system	224
" " , of Afghanistan	248
" " , of Jaunsar	222
" " , of Ngari Khorsum	256
" " , of Panjal system	224, 243
" " , Tertiary	238, 245

	PAGE.
Volcanoes, recent	256
Waddell, Colonel L. A.	62
Wahab, Colonel R. A.	11, 12, 18, 69, 97
Walker, General J. T.	22, 52, 73, 81, 111, 127, 128, 157
Waterfalls	141, 142, 143, 159
Water-parting between Aral and Tarim	108
" , Ganges-Brahmaputra	125
" , Himalayan, position of	138
" , Hunza-Gilgit	101
" , Indo-Tibetan	61, 125
" , Indus-Chenab	124
" , Indus-Jhelum	124
" , Indus-Tarim	121, 123
" , Indus-Tibet	124
" , north of Brahmaputra	95, 125, 271
" , of Brahmaputra in Tibet and Assam	92
" , Oxus-Helmund	122
" , Oxus-Indus	122
" , Oxus-Tarim	122
" , parallelism of, to Gt. Himalayan range	125
Water-parting, shifting of	124
Water-partings, primary	120
Waugh, Sir Andrew	14, 20, 25, 26, 27, 28
Webb, Captain W. S.	17, 18, 19, 137
Wellby, Captain M. C.	73, 110, 115
White, J. Claude	221
Willis, Bailey	253
Wind, effect of, in filling structural basins	65
" , excavation by	121
Wood, Captain H.	7, 20, 95, 113, 114, 149
" , Lieutenant J.	21
Woodthorpe, Captain R. G.	160
Workman, Dr. Hunter	22, 79, 175, 176, 269
" , Mrs. Bullock	14, 175, 176, 196, 269
" Zaskar " system	241, 242, 243, 244, 245
Zewan stage	244
Zones, stratigraphical, of the Himalaya	207

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Rupehu

Indus R.



Sirmur series

8 Lower Siwalik

9 Upper Siwalik

S. T I B E T A N Z O N E N.N.E. >

Sutlej R.



1 Gra

8 Ngari Khorsum volcanics

9 Lower Siwalik

10 Upper Siwalik

11 Pleistocene of Ngari Khorsum

S. B E T A N Z O N E N. >

Eastern extension of Ladak range

Brahmaputra

Eastern extension of Kailas range

Plains



Cretaceous and Eocene)

7 Siwalik series

FOLDING IN THE SUB-HIMALAYAN ZONE

PLATE XXXIX

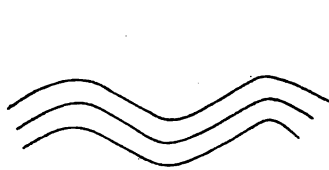


Fig. 1. Simple folding.

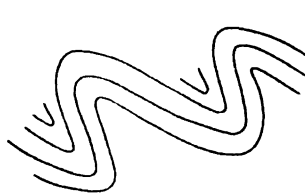


Fig. 2. Reversed folding.

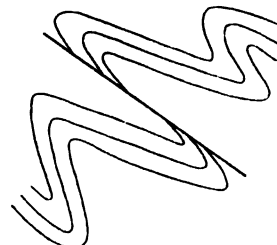


Fig. 3. Overthrust.

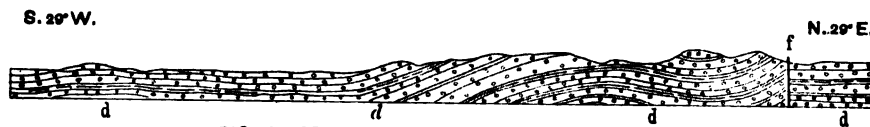


FIG. 4. SECTION THROUGH THE KOTAH DUN.

Scale 1 Inch = $1\frac{1}{2}$ Miles.

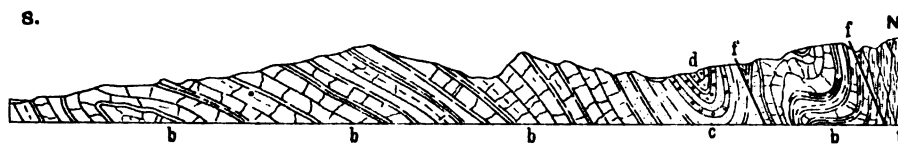


FIG. 5. SECTION WEST OF KALAUNIA NADI.

Scale 1 Inch = $1\frac{1}{2}$ Miles.

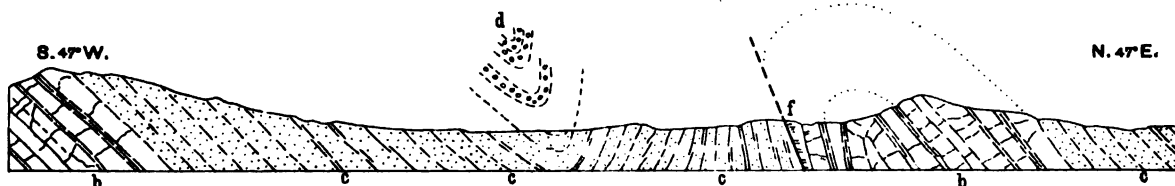


FIG. 6. SECTION ACROSS THE SONA NADI.

Scale 1 Inch = 1 Mile.



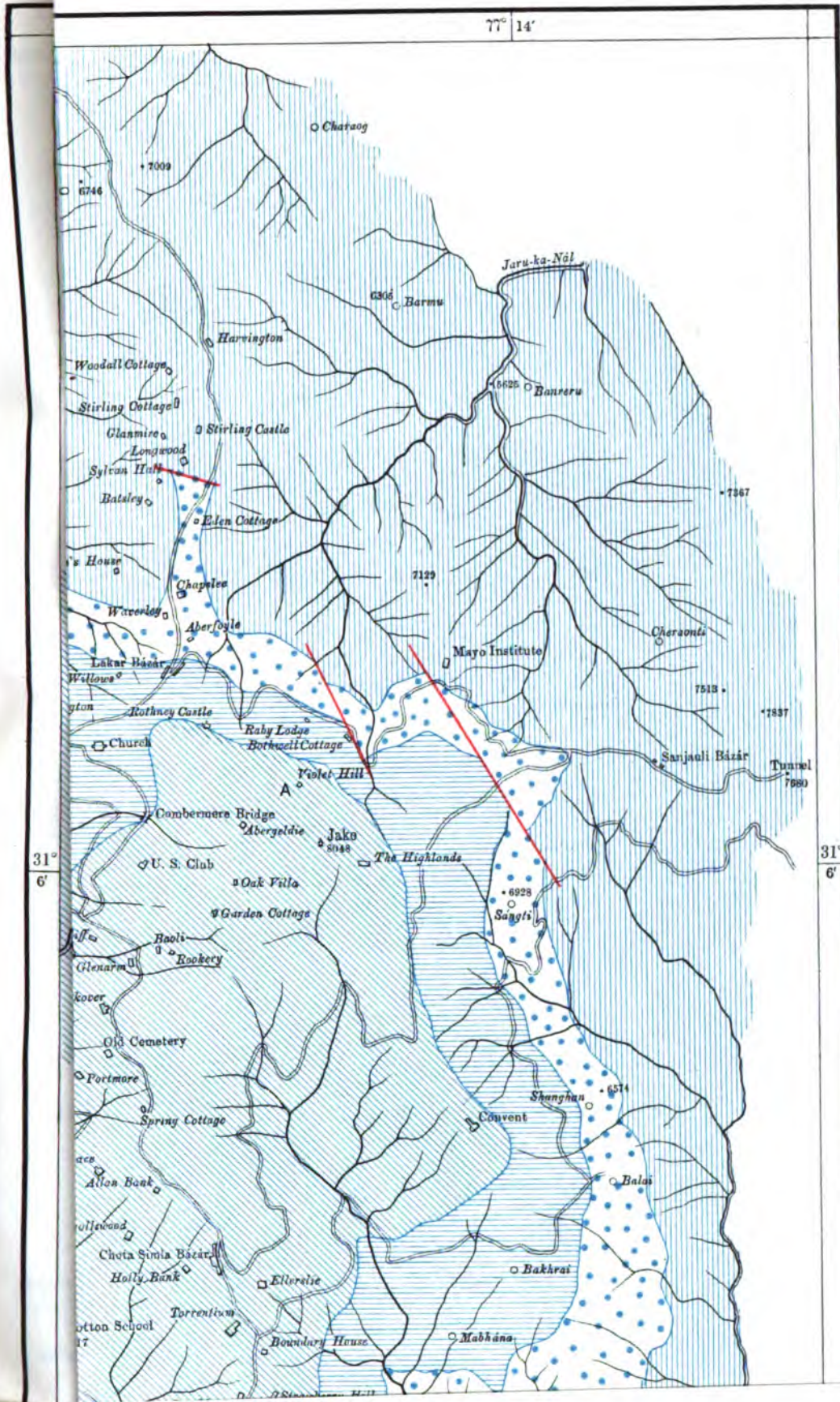
FIG. 7. SECTION EAST OF THE GANGES.

Scale 1 Inch = $1\frac{1}{2}$ Miles.

FIGS. 4 to 7. SECTIONS THROUGH THE SUB-HIMALAYA OF GARHWAL AND KUMAUN.

(after C. S. Middlemiss. Mem., Geological Survey of India, XXIV, Pt. 2.)

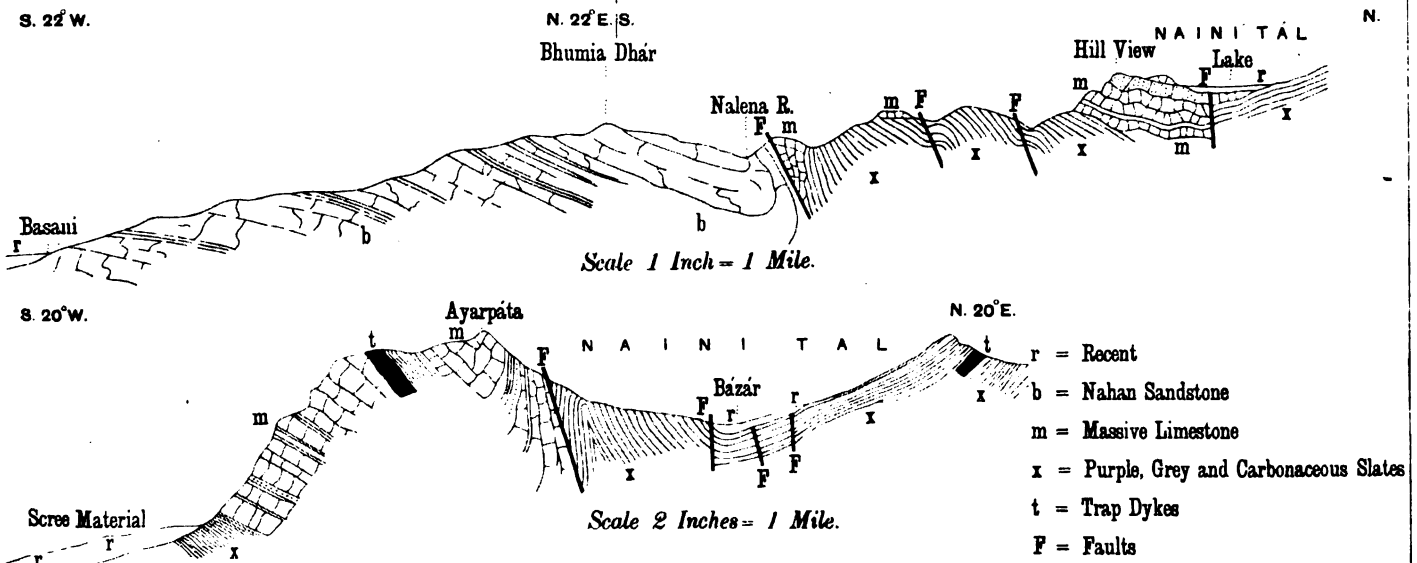
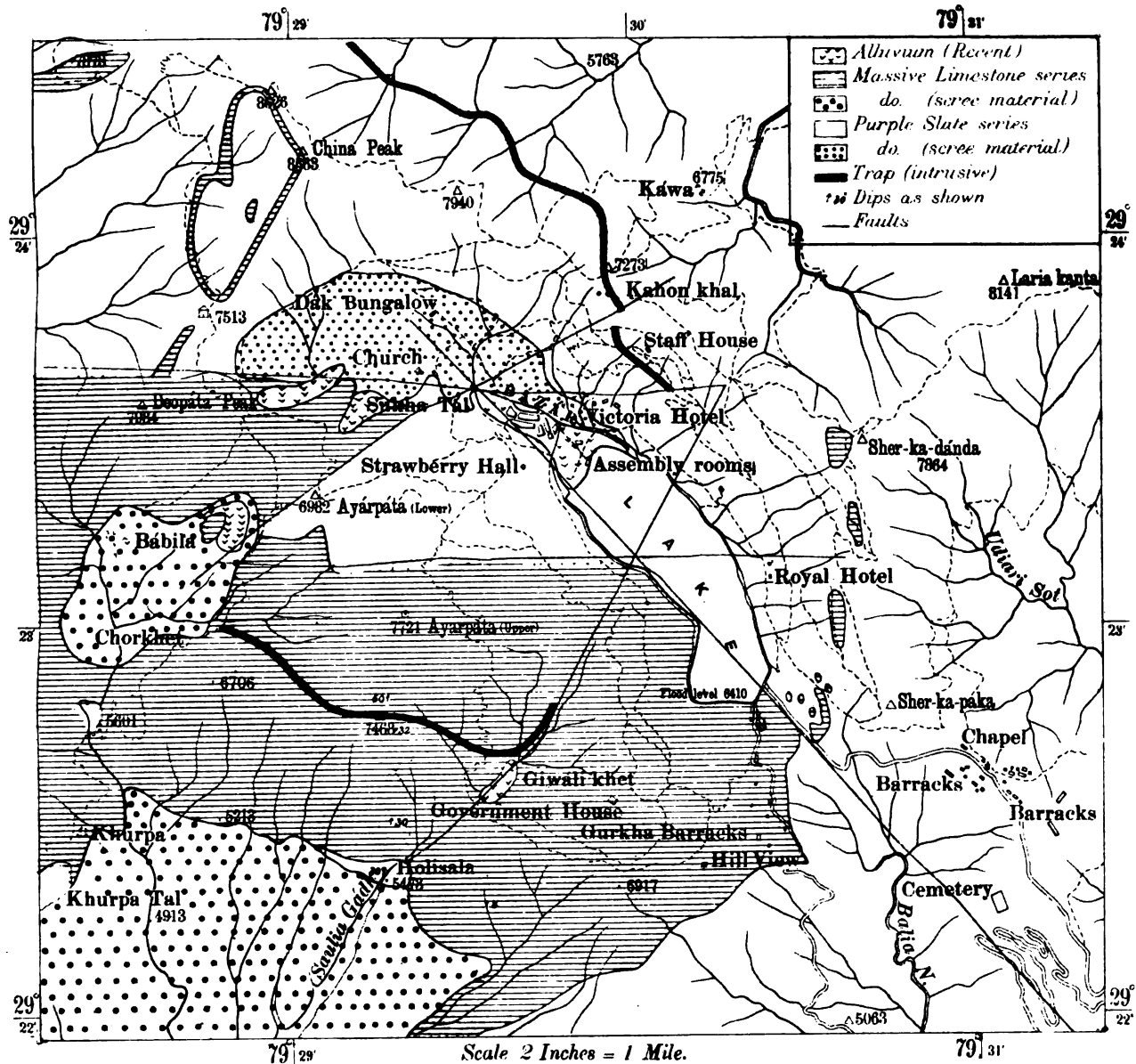
- | | |
|-----------------------------------|-------------------------|
| r = Recent. | n = Tal series. |
| d = U. Siwalik Conglomerate. | t = Trap. |
| c = M. Siwalik sand rock. | x = Purple slate. |
| b = L. Siwalik (Nahan) sandstone. | z = Crystalline schist. |
| a = Nummulitic. | f = Faults. |



GEOLOGICAL MAP AND SECTIONS OF NAINI TÁL

(after C. S. Middlemiss: *Rec., Geological Survey of India XXIII*)

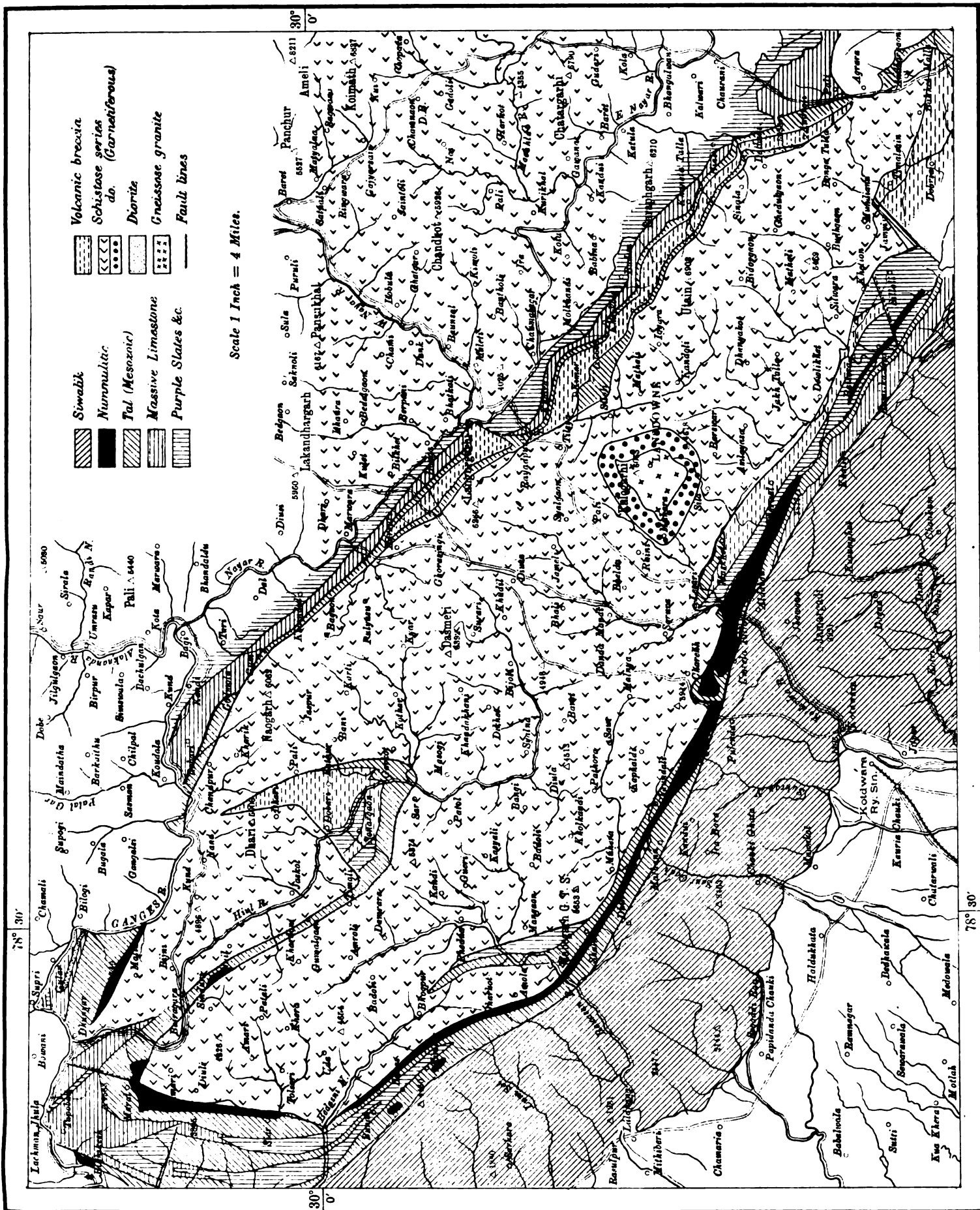
PLATE XLI



TAL SERIES IN WESTERN GARHWAL

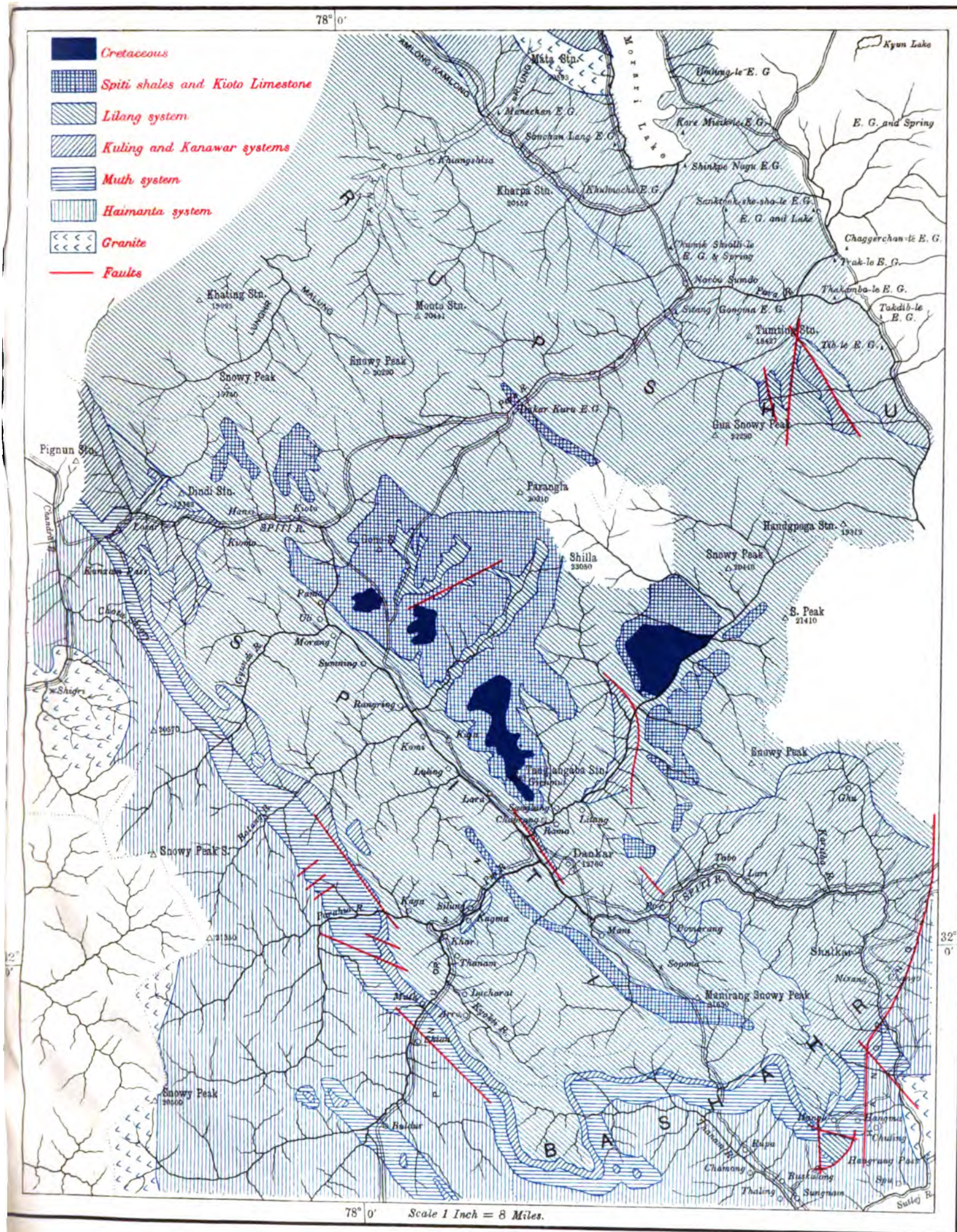
(after C. S. Middlemiss: Rec., Geological Survey of India, I.X)

PLATE XLII



(after H. H. Hayden and A. von. Krafft: *Mém., Geological Survey of India, XXXVI, pl. 1*)

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SECTIONS ACROSS THE TIBETAN ZONE IN SPITI, TIBET AND KUMAUN

PLATE XLIV

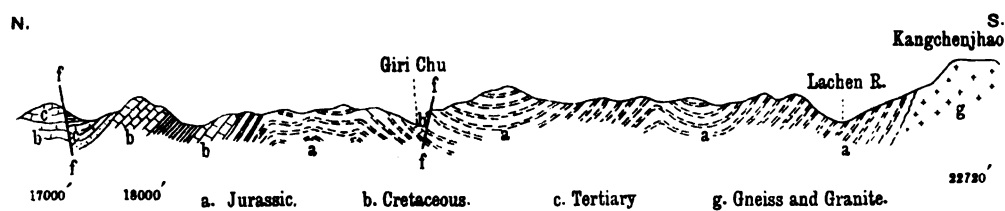


FIG. 1. SECTION FROM KANGCHENJHAO TO KAMPA RIDGE, TIBET.
(after H. H. Hayden, *Mem., Geological Survey of India, XXXVI, pt. 2*)
Scale 1 Inch = 4 Miles.

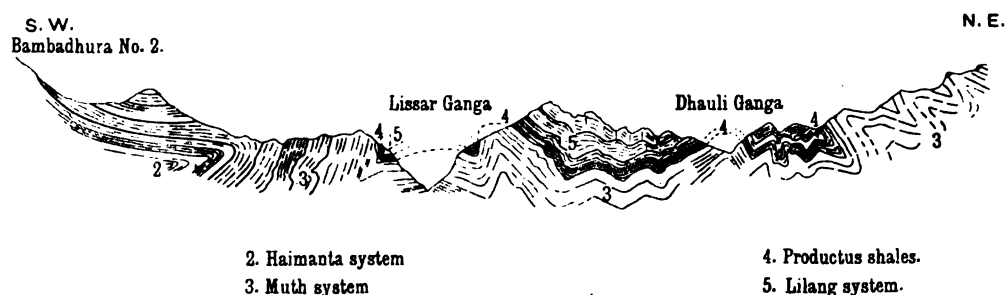


FIG. 2. SECTION BETWEEN THE EAST SLOPE OF THE BAMBADHURA AND THE DHAULI GANGA, KUMAUN.
(after C. L. Griesbach, *Mem., Geological Survey of India, XXIII*)
Scale 1 Inch = 2 Miles.

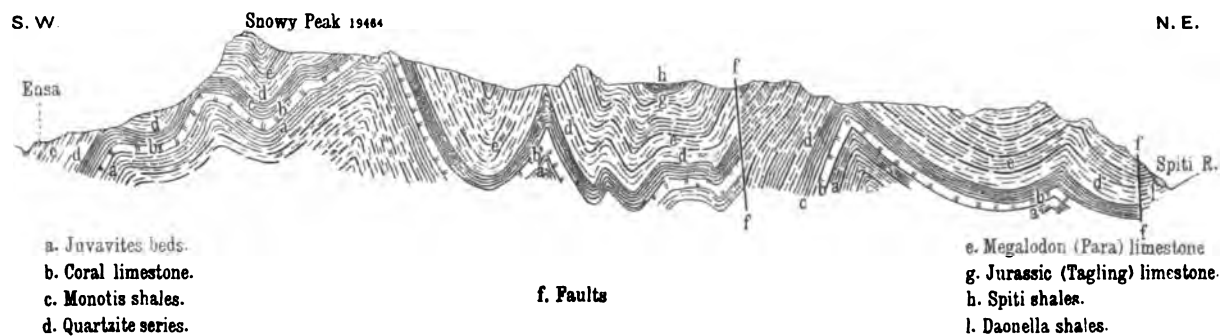


FIG. 3. SECTION FROM SPITI RIVER, ABOVE MANI, TO ENSA.
(after H. H. Hayden, *Mem., Geological Survey of India, XXXVI, pt. 1.*)
Scale 1 Inch = 2 Miles.

SECTIONS ACROSS THE TIBETAN ZONE IN SPITI, KUMAUN AND HAZÁRA

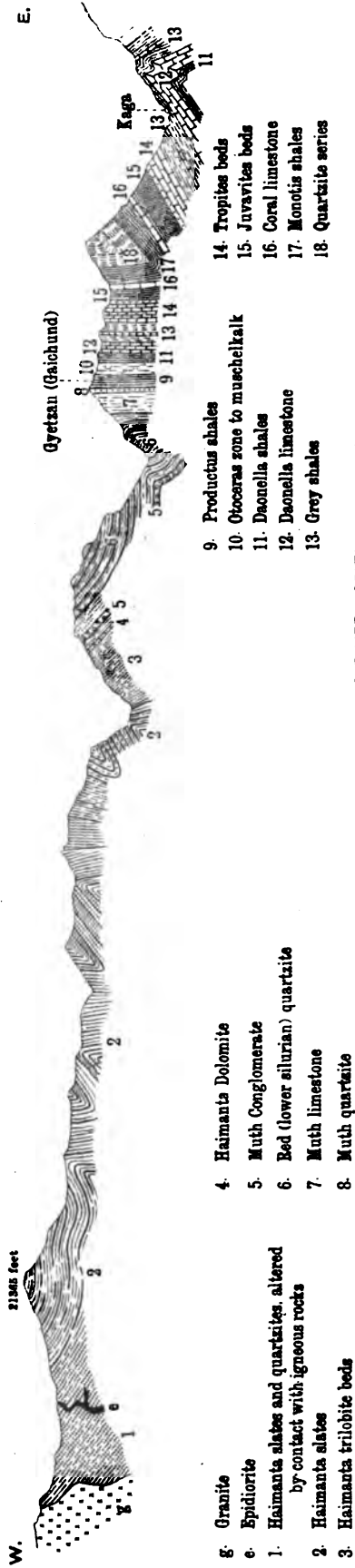


FIG. 1.—SECTION ALONG THE PARAHIO RIVER, SPITI.
(after H. H. Hayden: *Mem., Geological Survey of India, XXXVI, pt. 1*)

Scale 1 Inch = 2 Miles.



FIG. 2.—SECTION BETWEEN THE NAULPHU NIPCHUNG HEIGHTS AND THE RANGE WHICH DIVIDES
THE KUTI YANGTI FROM HUNDES, SOUTH OF THE MANKSHANG.

(after C. L. Griesbach: *Mem., Geological Survey of India, XXIII*)

Scale 1 Inch = 3 Miles.

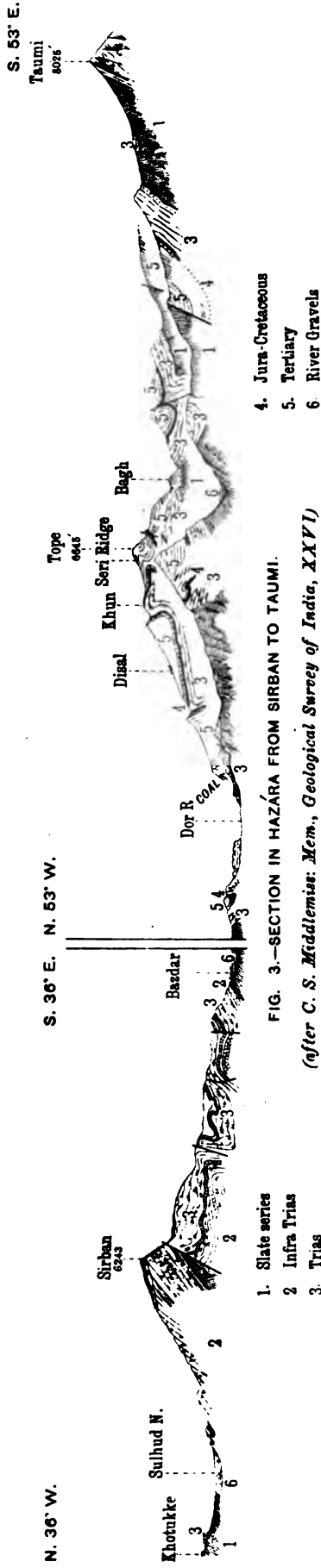


FIG. 3.—SECTION IN HAZÁRA FROM SIRBAN TO TAUMI.
(after C. S. Middlemist: *Mem., Geological Survey of India, XXVI*)

Scale 1 Inch = 1 Mile.

GEOLOGICAL MAP AND SECTIONS OF MALLA JOHÁR

(after A. von. Kraft: Mem., Geological Survey of India, XXXII, pt. 3)

PLATE XLVI

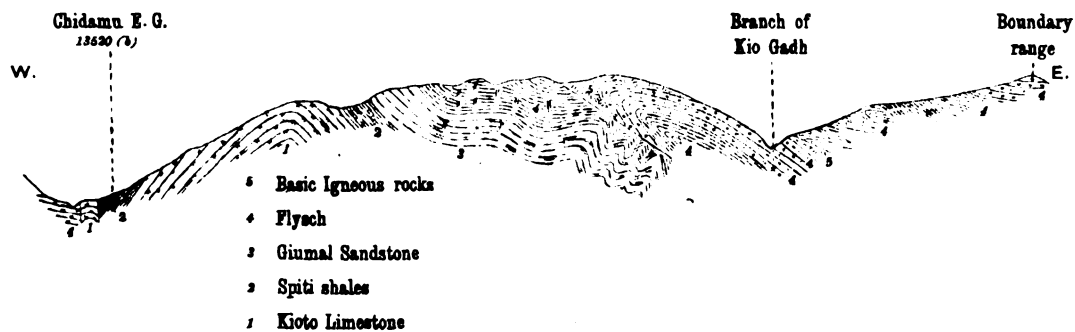


FIG. 2. SECTION THROUGH COUNTRY S. OF THE KIO GADH.

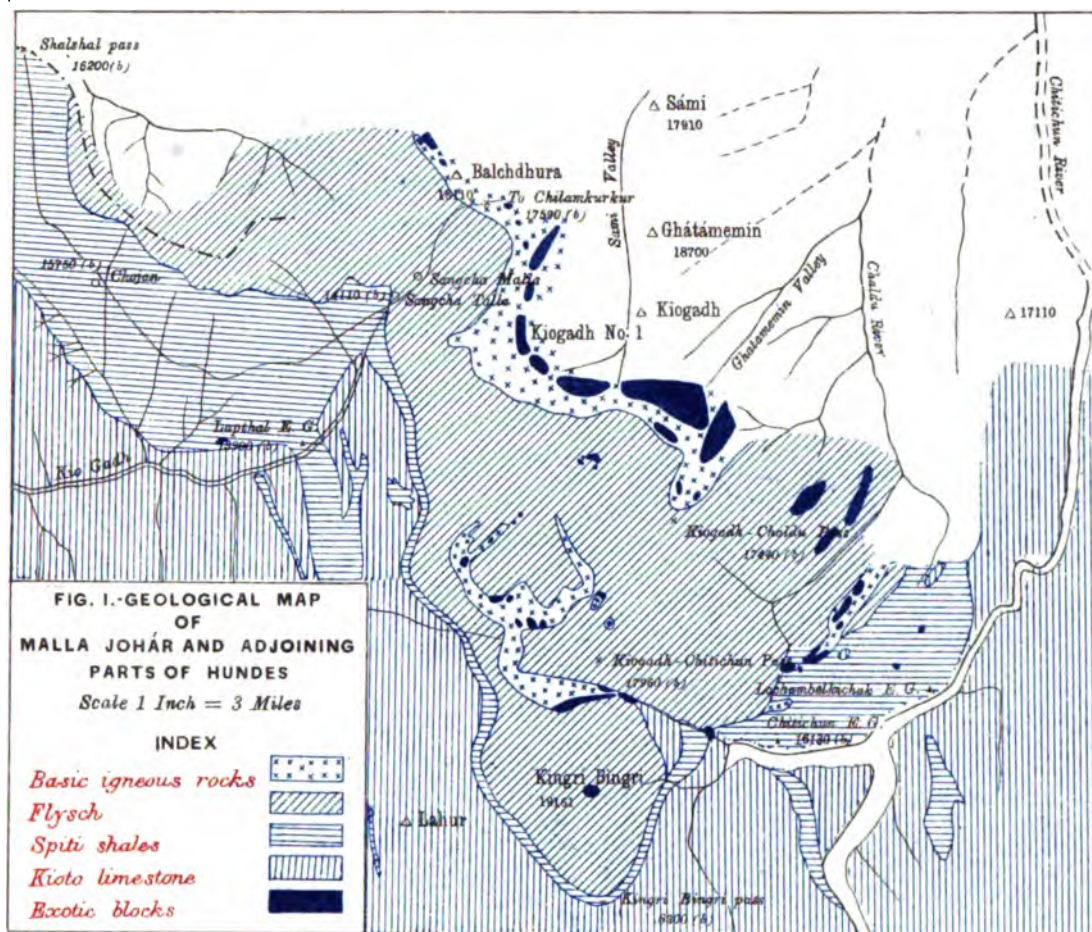


FIG. 1.-GEOLOGICAL MAP
OF
MALLA JOHÁR AND ADJOINING
PARTS OF HUNDES
Scale 1 Inch = 3 Miles

INDEX

- Basic igneous rocks
- Flysch
- Spiti shales
- Kioto limestone
- Exotic blocks

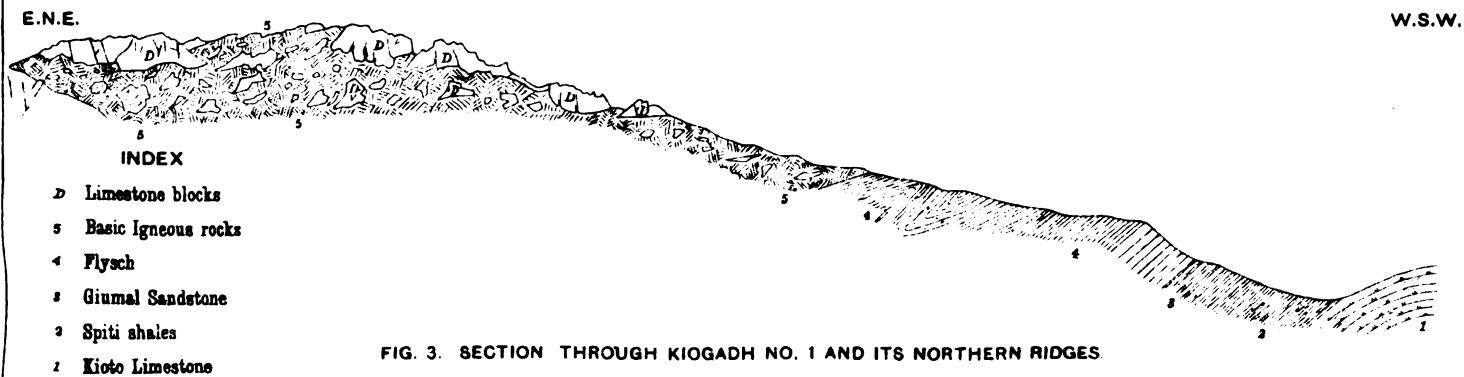


FIG. 3. SECTION THROUGH KIOGADH NO. 1 AND ITS NORTHERN RIDGES

(after H.H. Hayden: *Mem., Geological Survey of India, XXXVI, Pt. 2*)

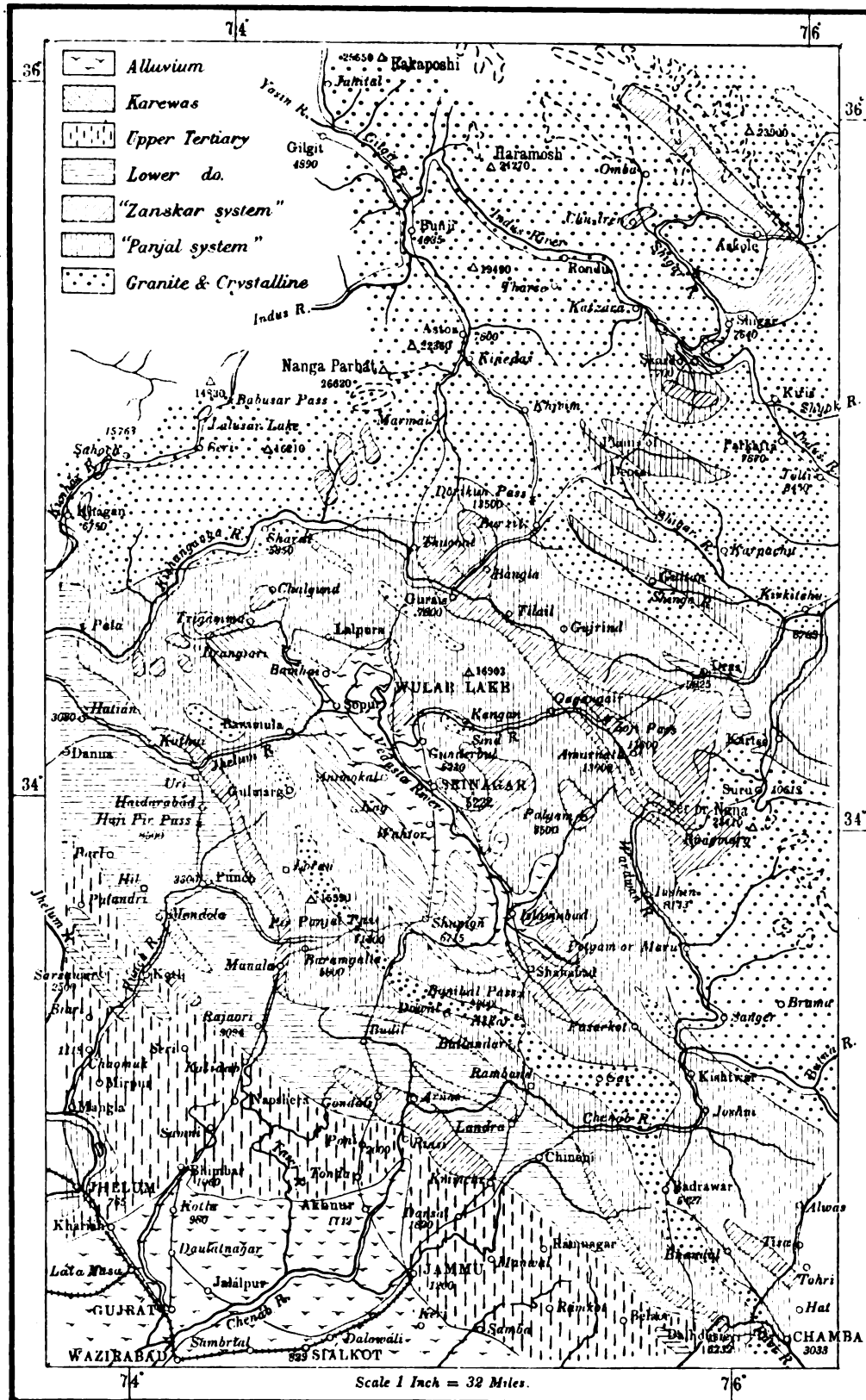
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GEOLOGICAL MAP OF KASHMIR

(after R. Lydekker: Mem., Geological Survey of India, XXII.)

PLATE XLVIII

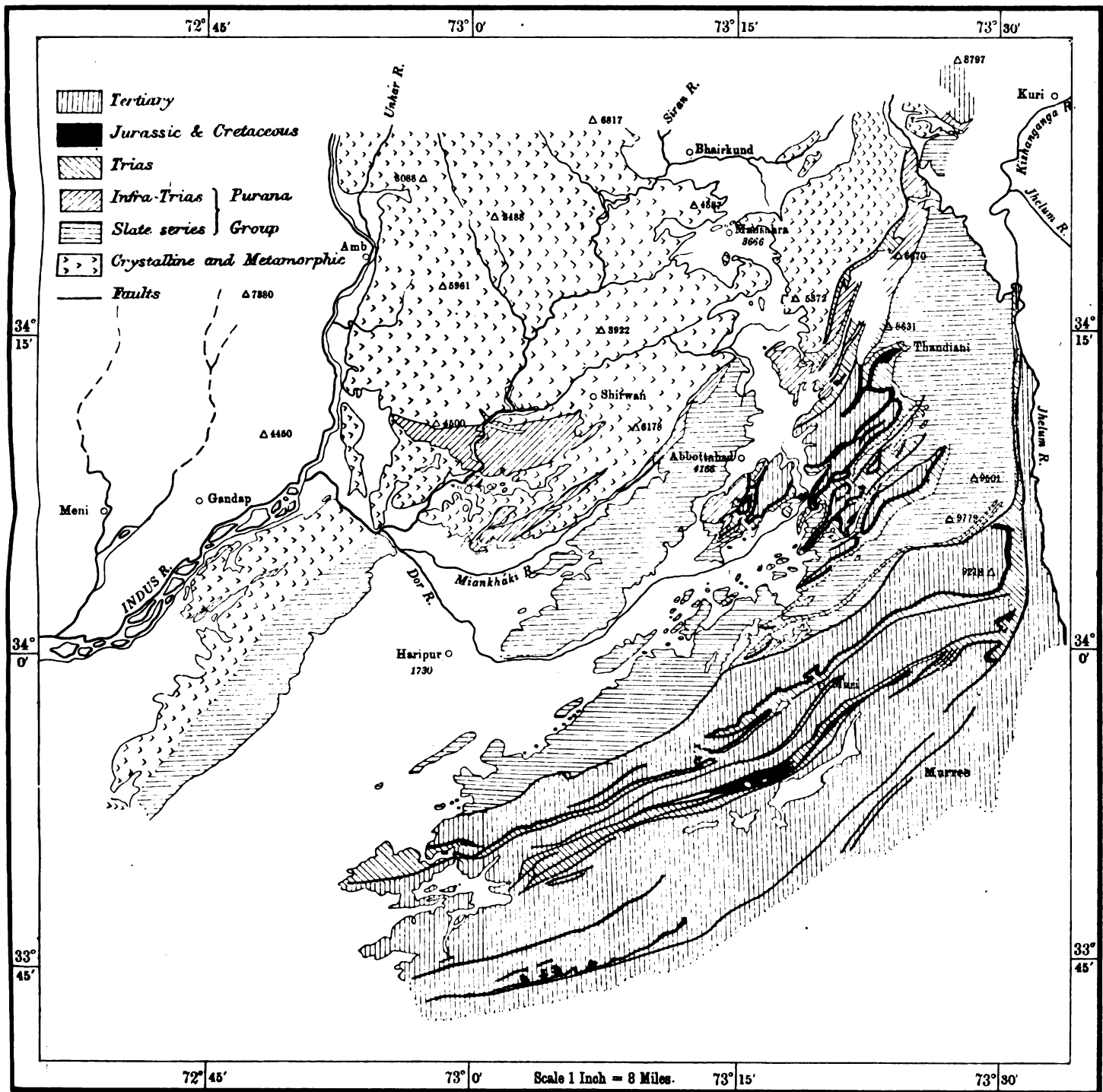


Hellu T. B. O. Dehra Doo.

GEOLOGICAL MAP OF HAZÁRA

(after C. S. Middlemiss: *Mem., Geological Survey of India*, XXVI).

PLATE XLIX



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